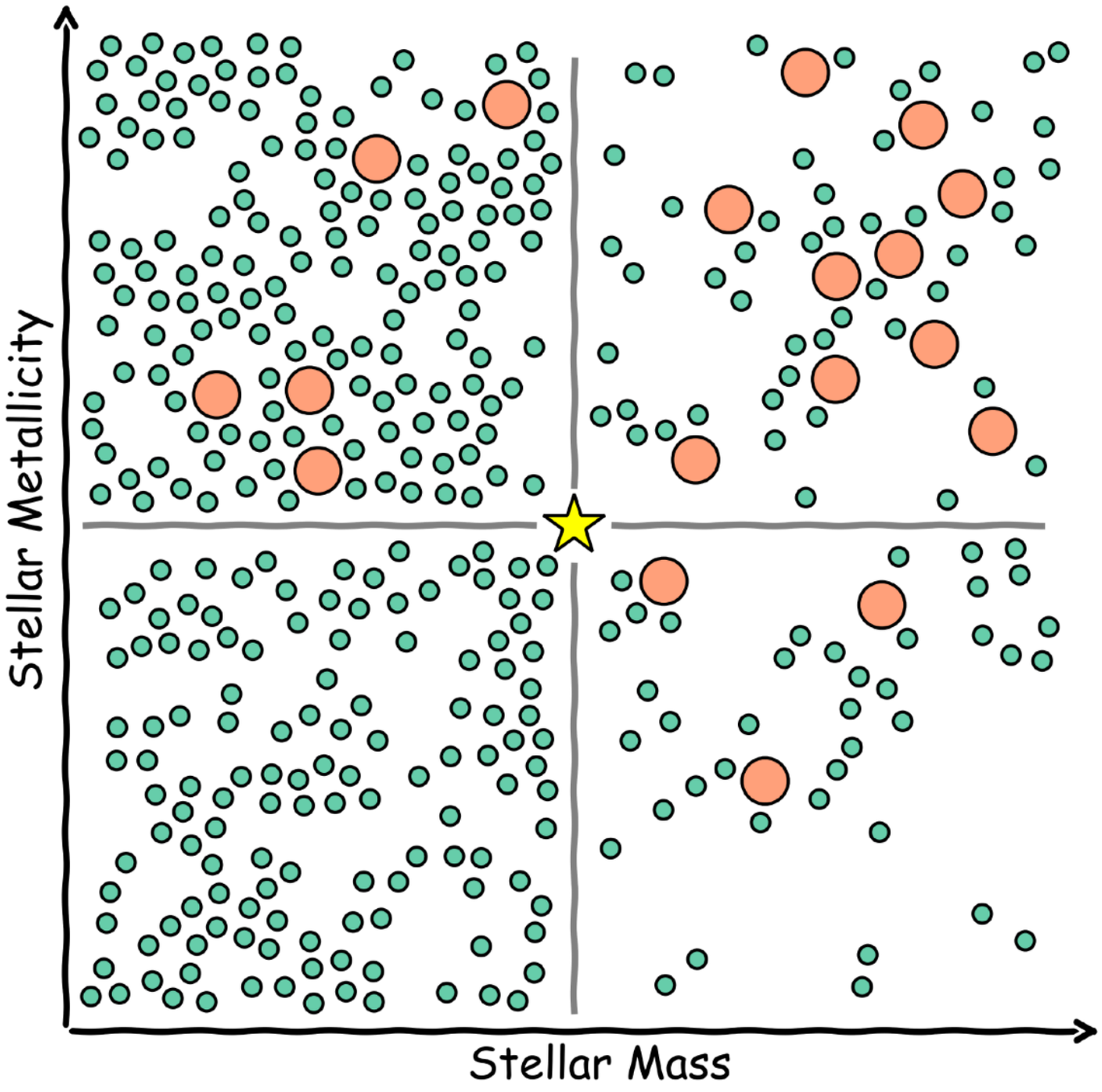
The exoplanet population around stars of different masses

Gijs Mulders
University of Chicago



The Kepler Exoplanet Population Around Different Types of Stars

Mulders 2018 (Handbook of Exoplanets)

Conclusion

Planets occur more frequently around low-mass stars...

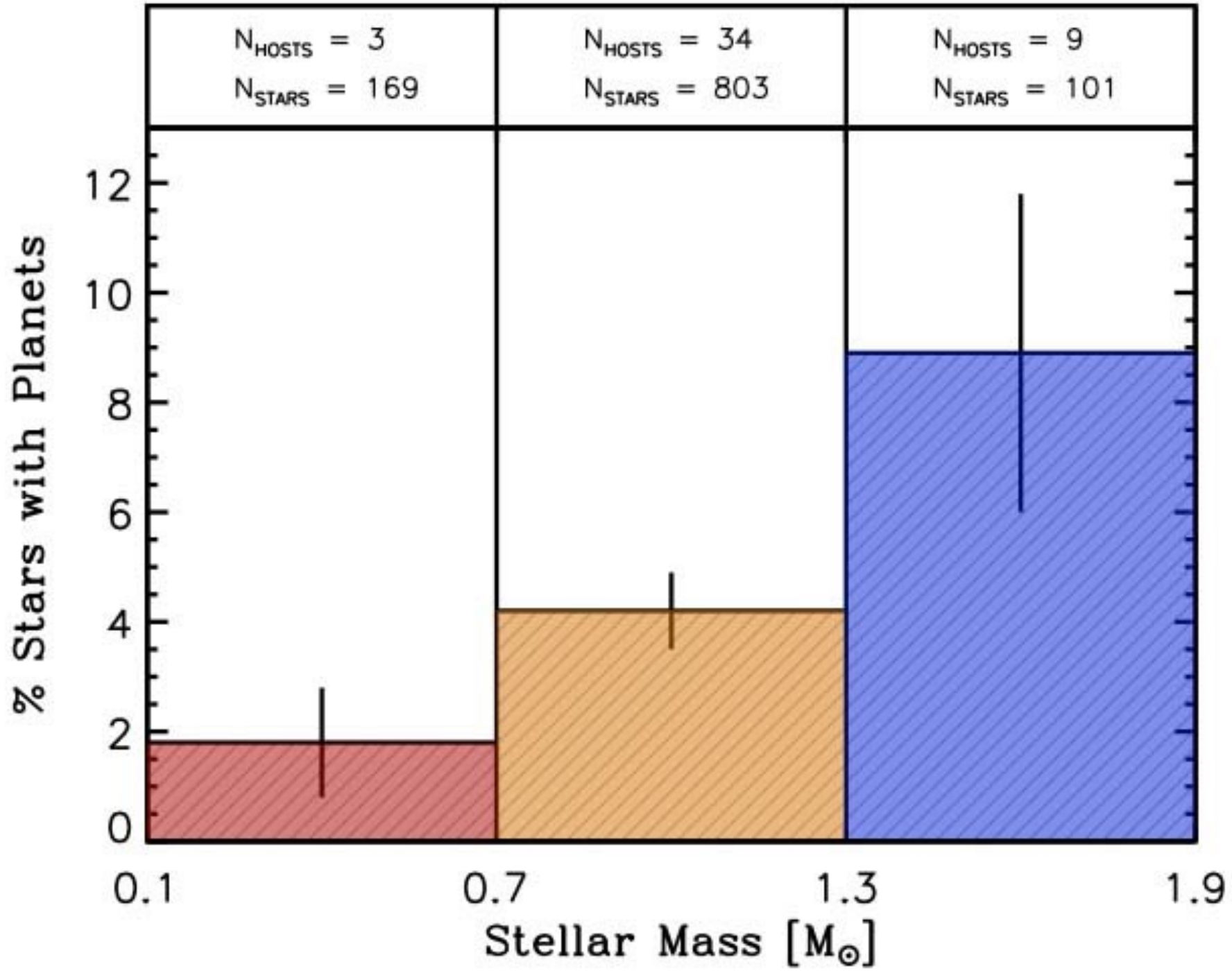
Conclusion

Planets occur more frequently around low-mass stars...

Discussion

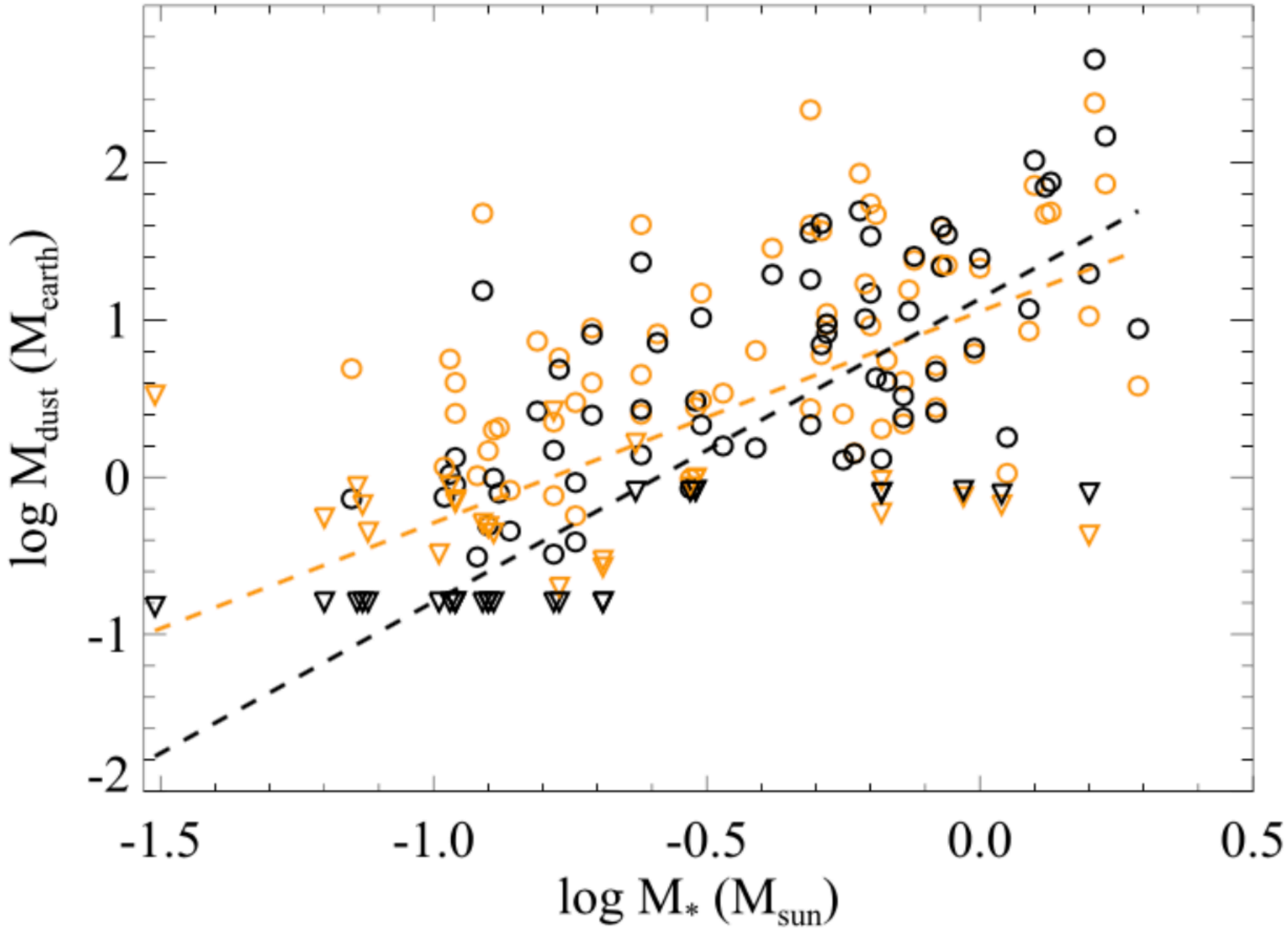
...but we do not understand the implications for planet formation

pre-Kepler



Giant Planets Occurrence increases with stellar mass

Johnson+ 2010



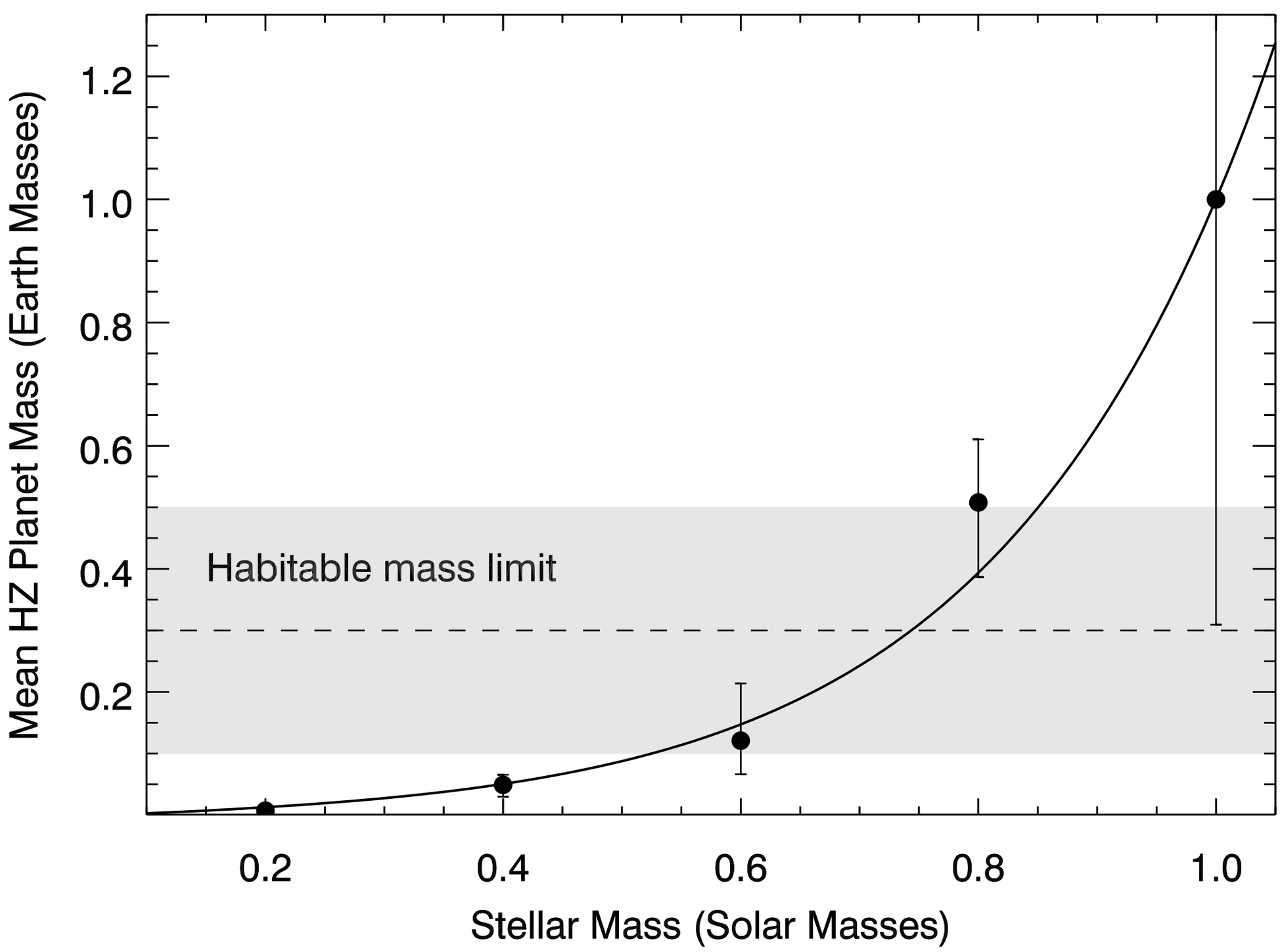
Disk Mass correlated with stellar mass

Pascucci+ 2016

Star-Planet Connection

Star-Disk-Planet Connection

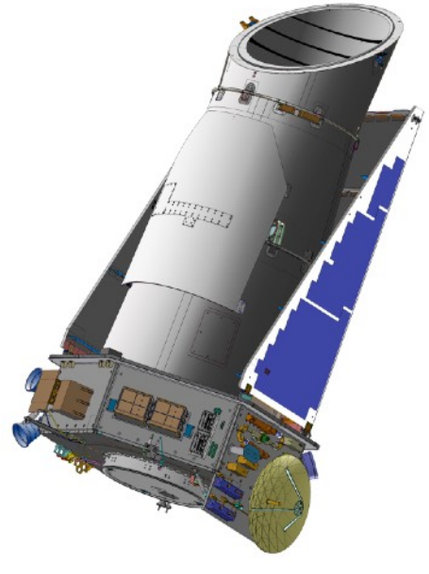
Star-Disk-Planet Connection

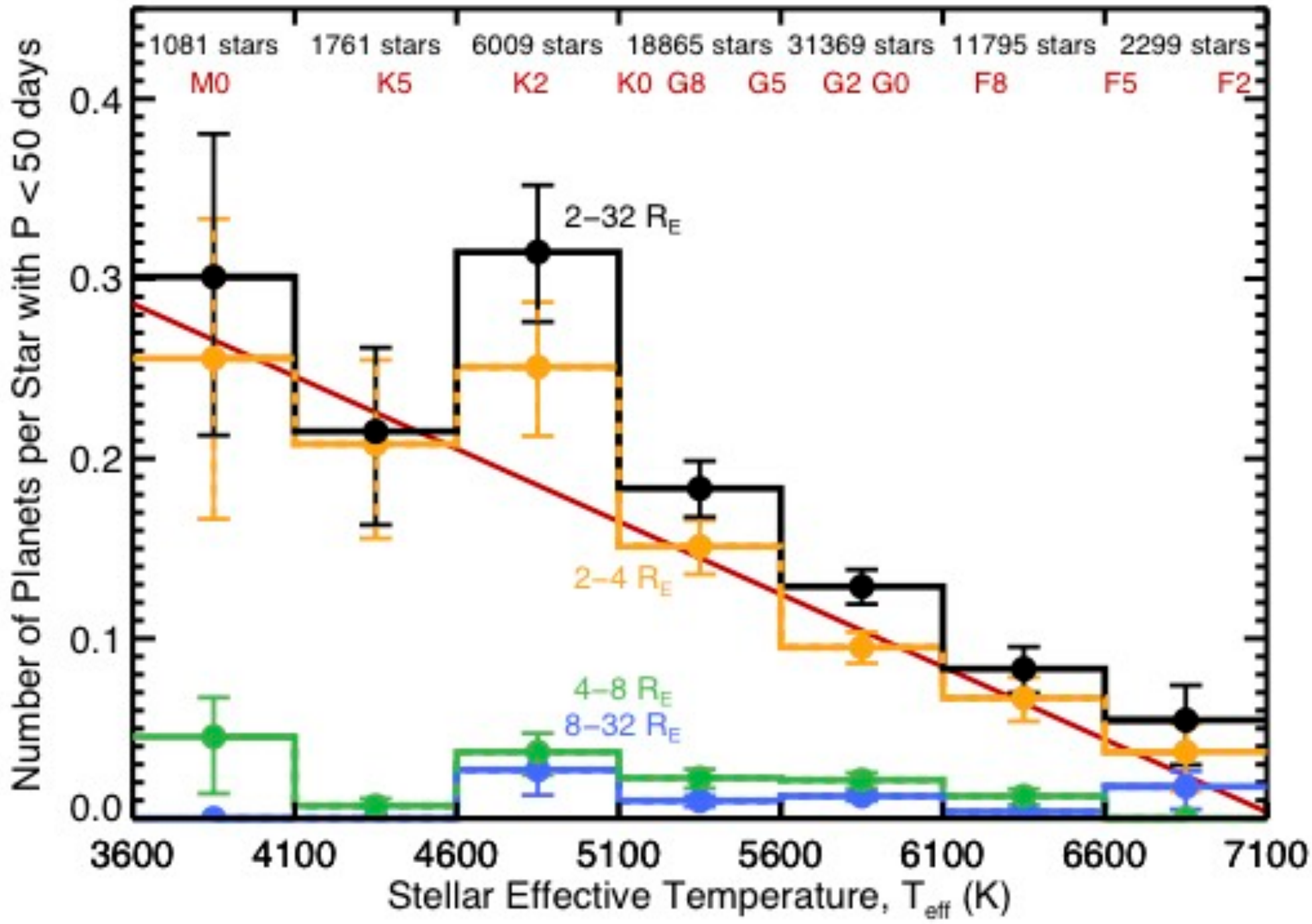


Expectation: Habitable zone planets around M stars are small and dry

Raymond+ 2007, Lissauer 2007

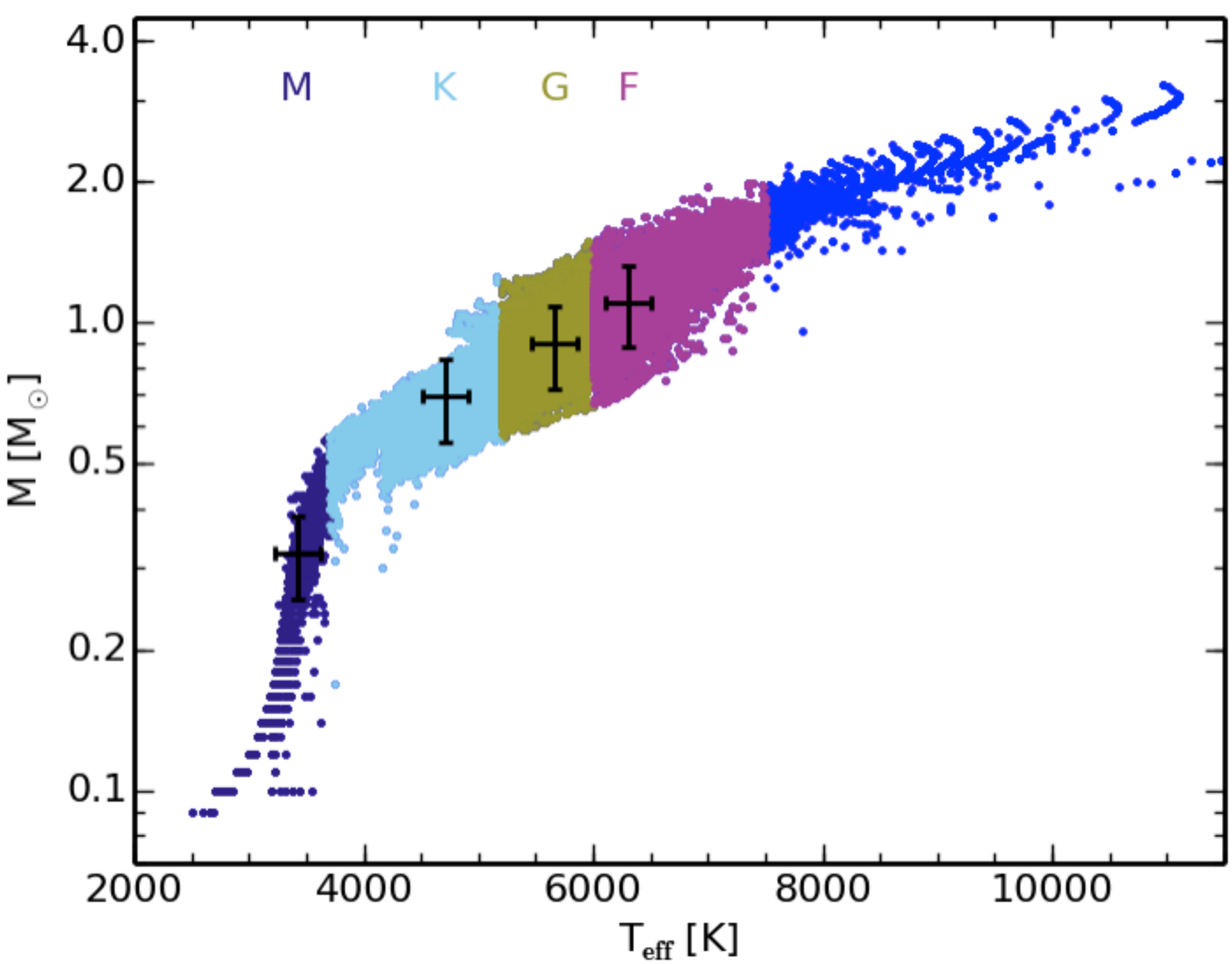
Kepler





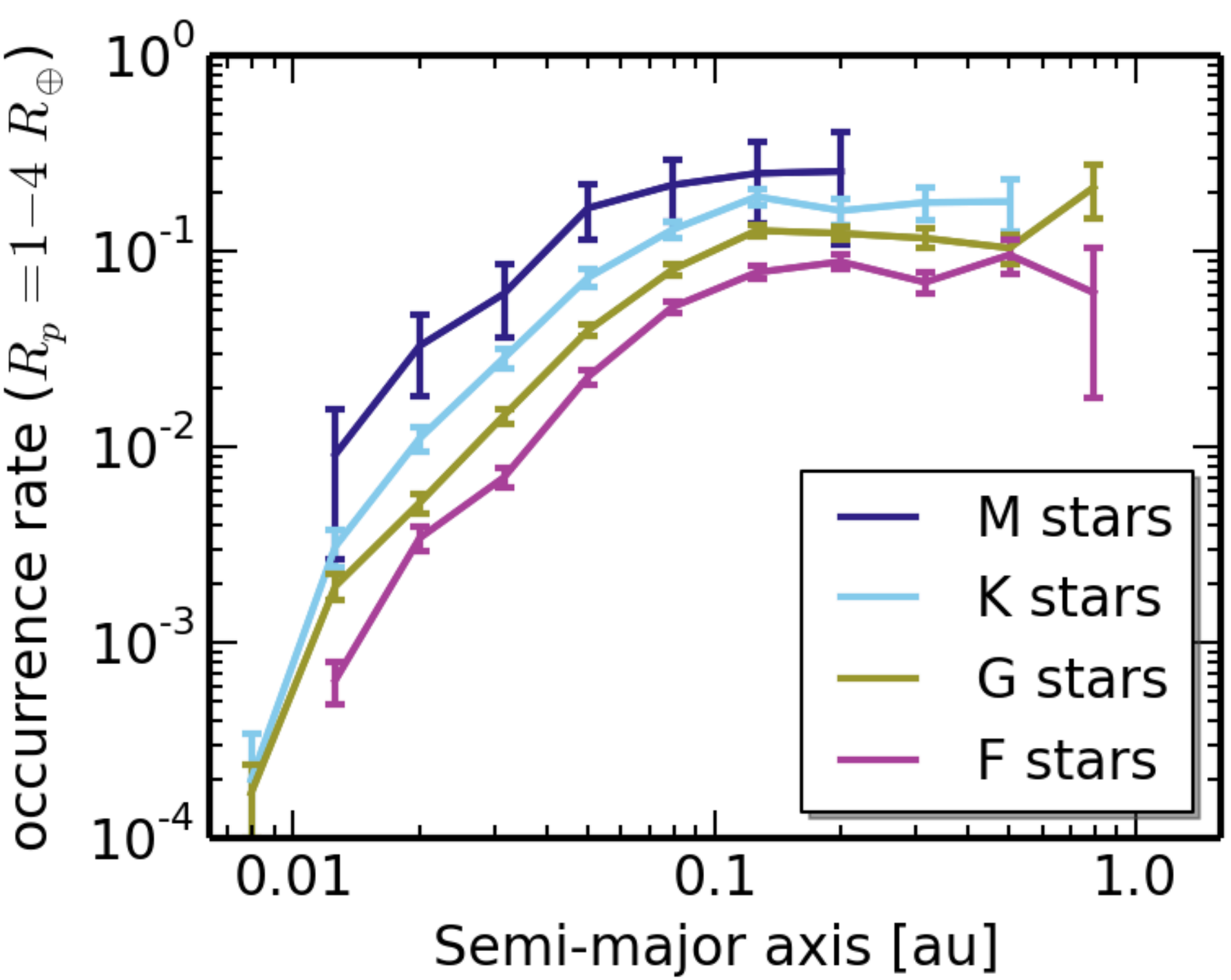
Planet occurrence decreases with effective temperature

Howard+ 2012



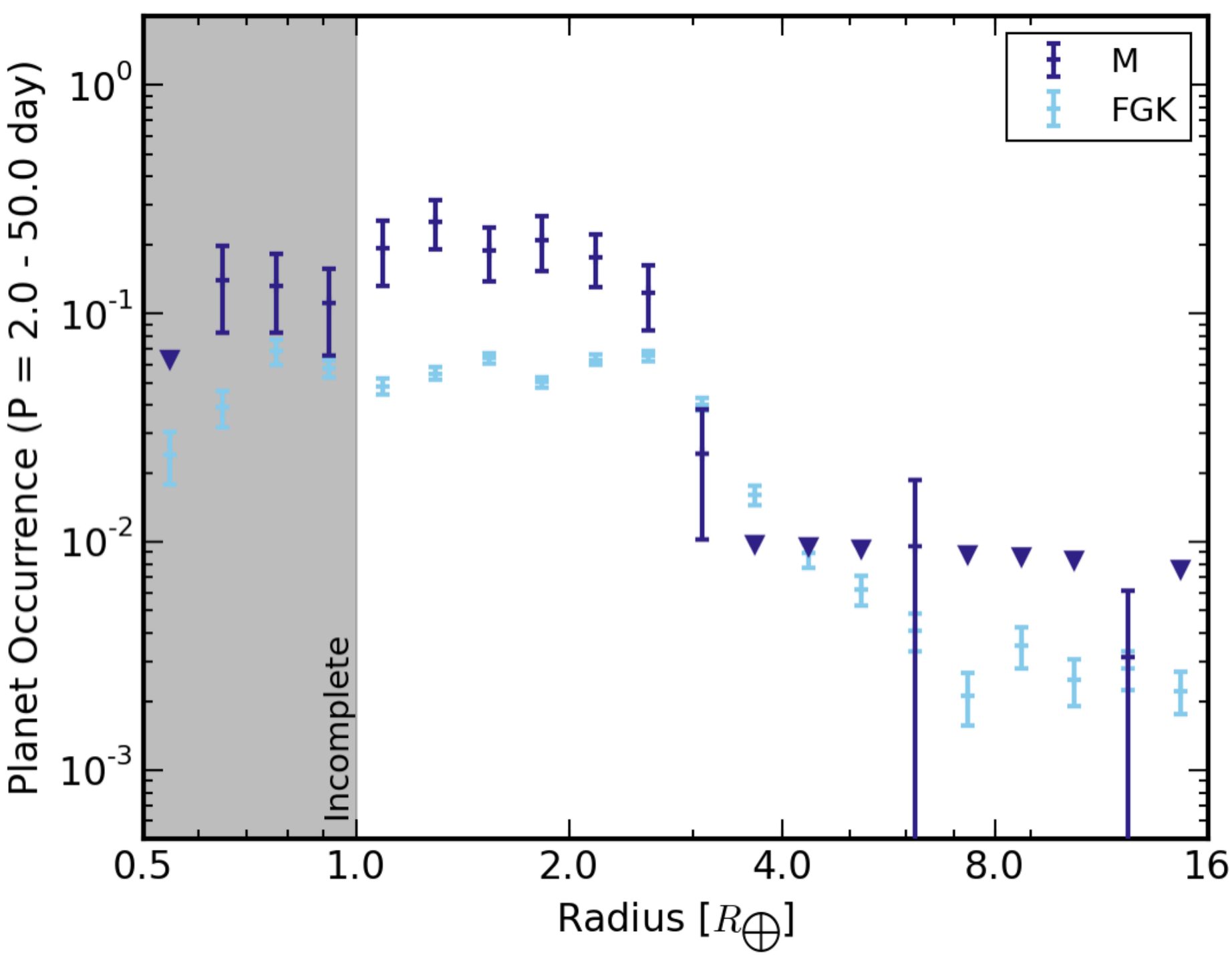
Spectral type as proxy for Stellar Mass

Huber+ 2014, Dressing & Charbonneau 2013



Same spatial distribution:
Low-mass stars have more planets!

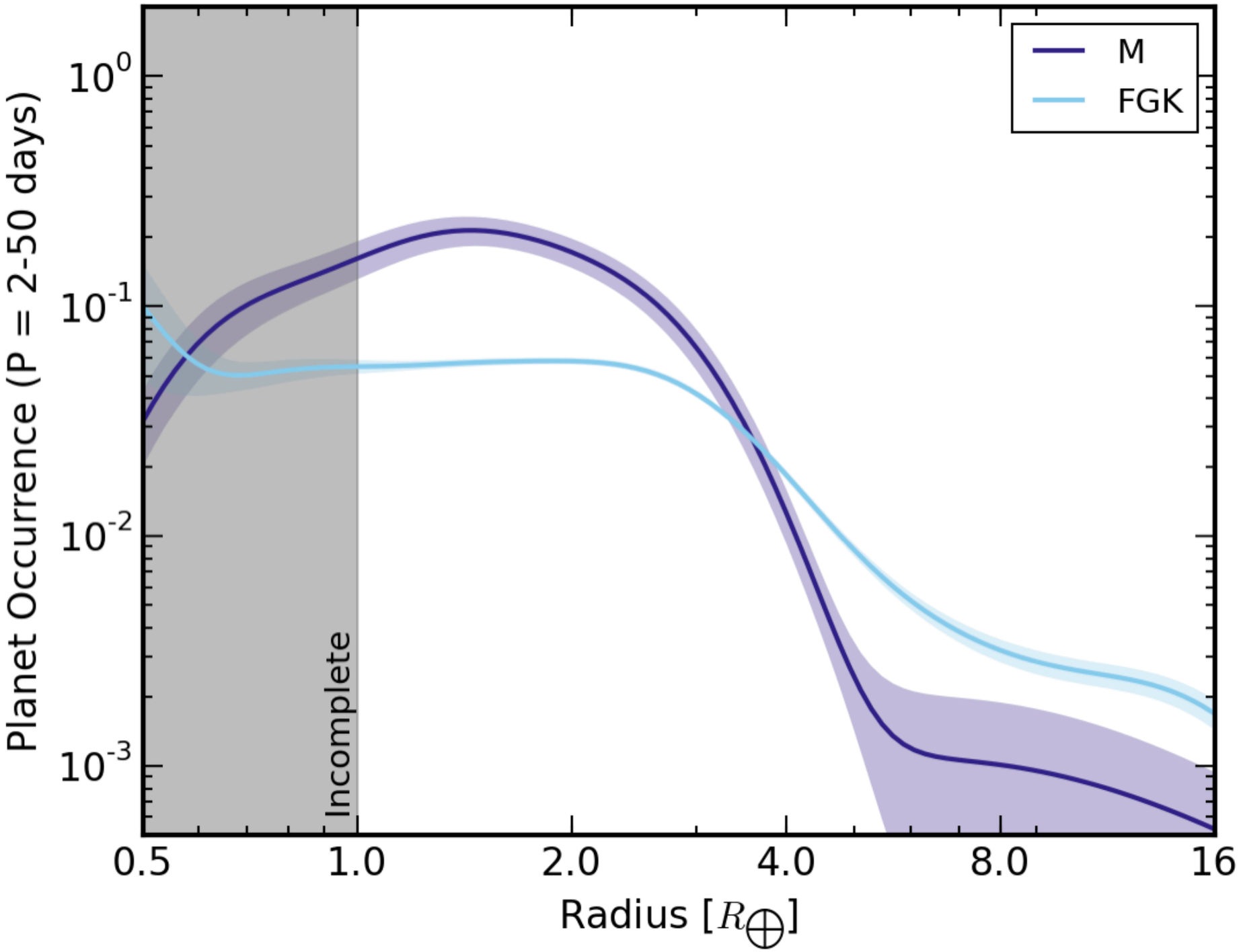
Mulders et al. 2015a



Planet Radius Distribution

Low-mass stars have more sub-Neptunes!

Mulders et al. 2015b



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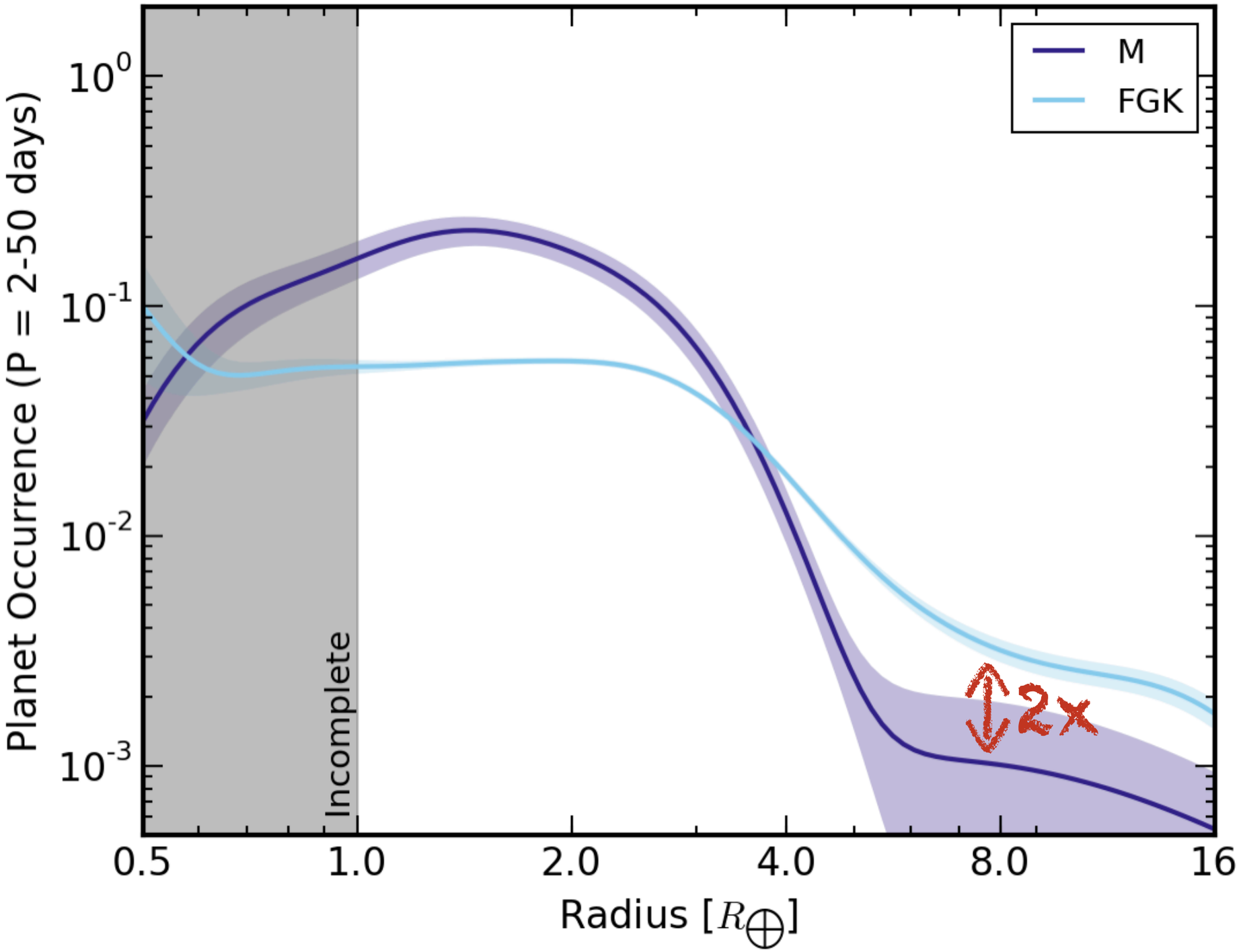

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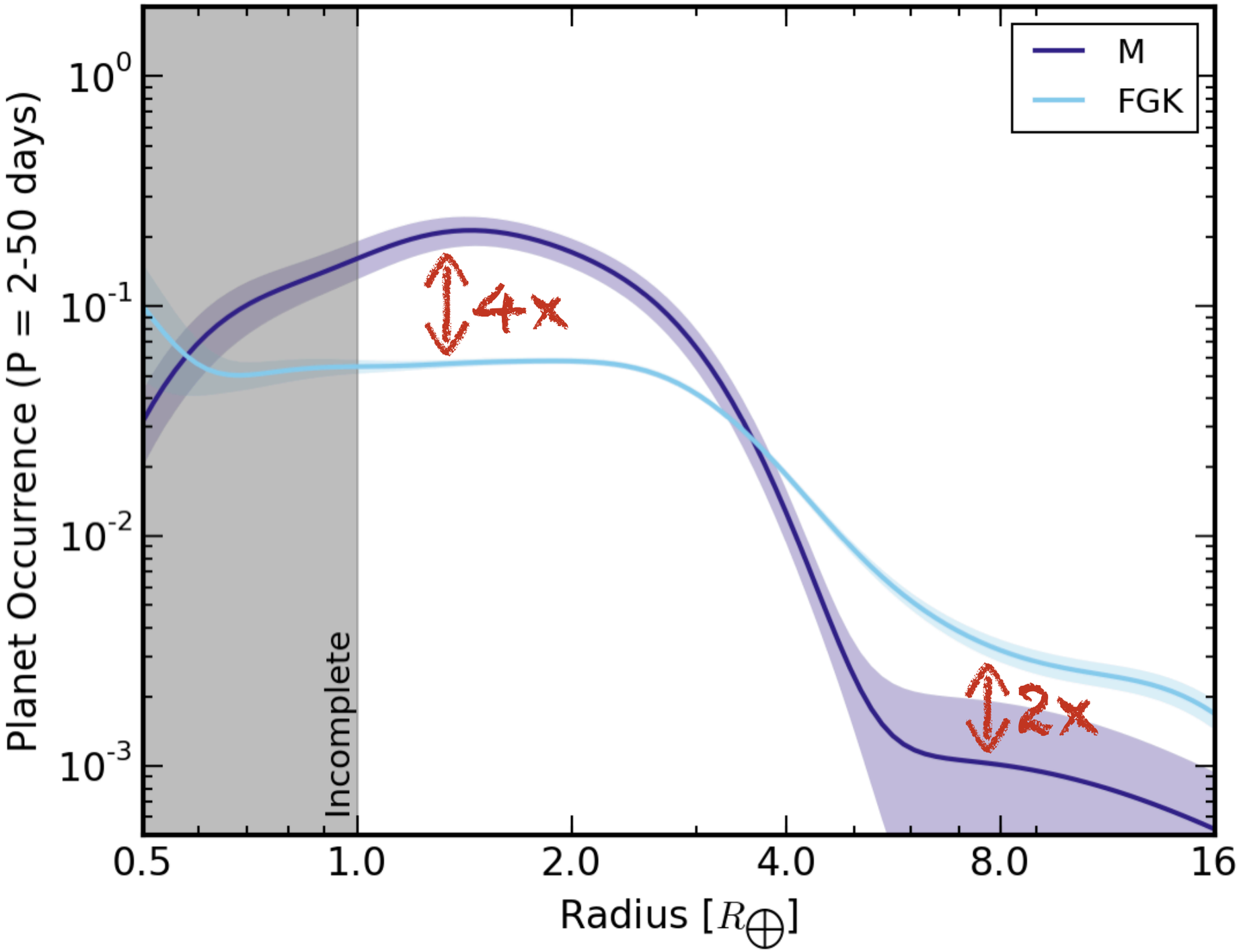

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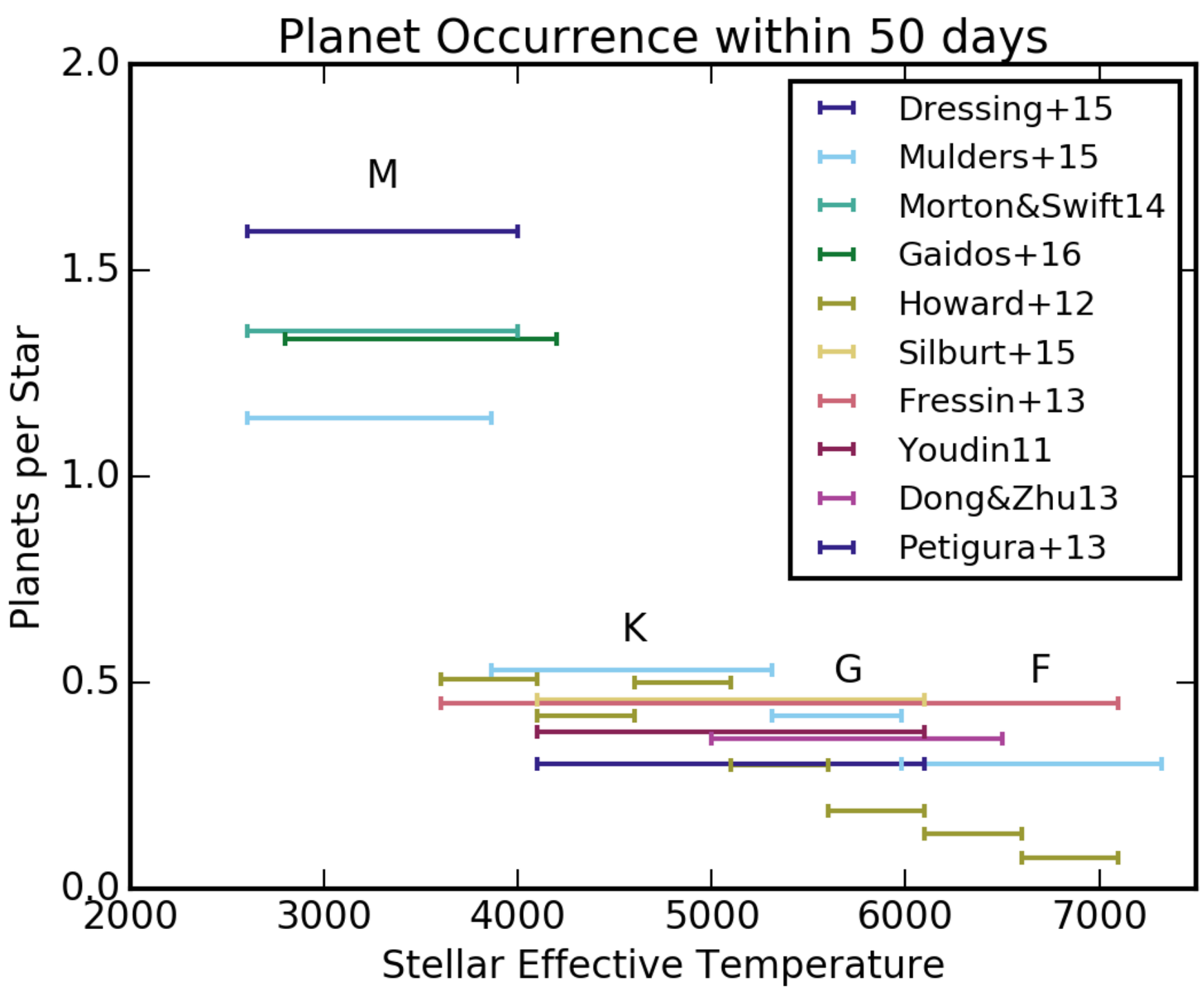
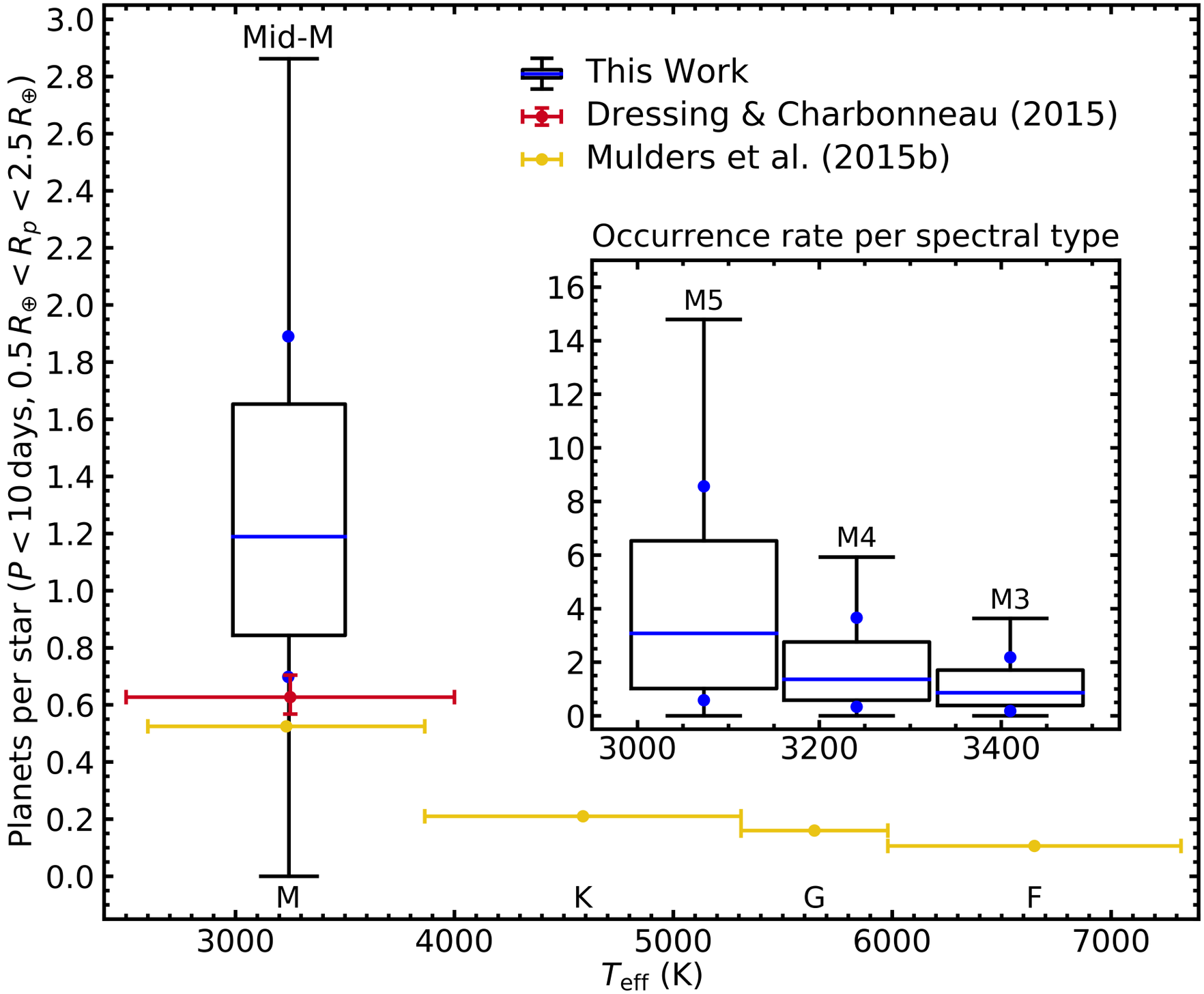


Low-mass stars have more sub-Neptunes

Mulders 2018, Handbook of Exoplanets



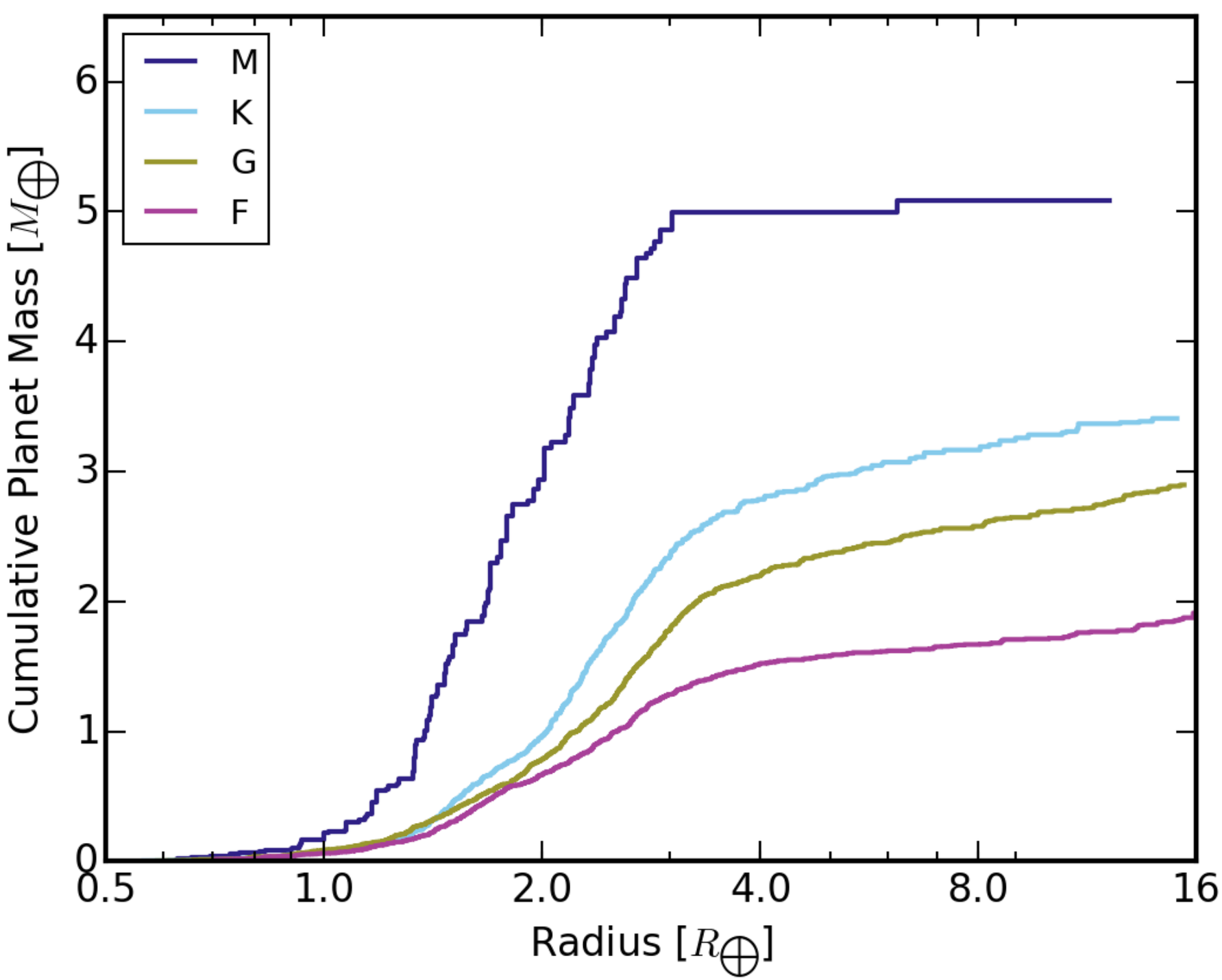
Trend continues for mid-M dwarfs

Hardegree-Ullmann+ 2019

Why?

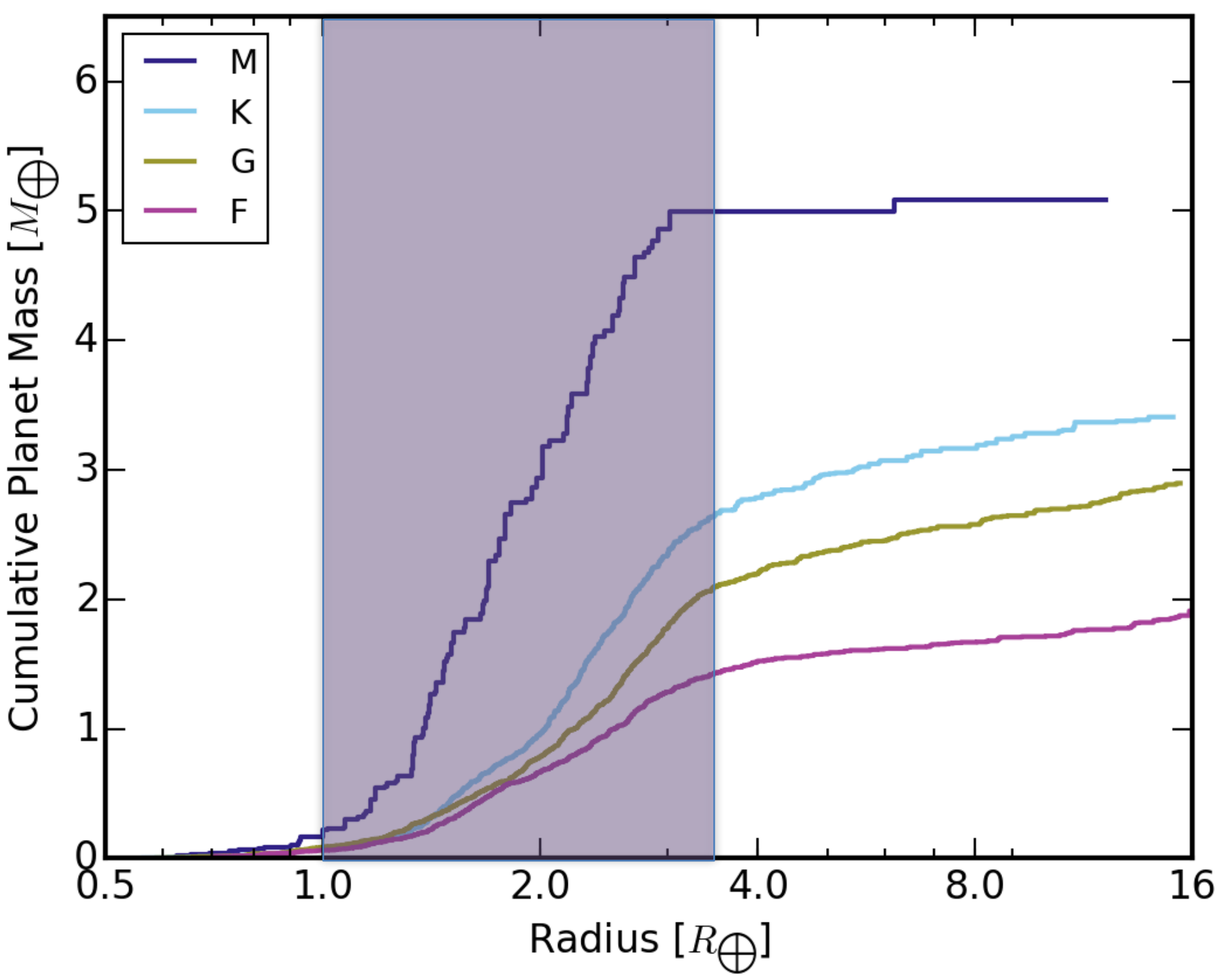
How to explain elevated occurrence rate for M dwarfs planets

- Detection biases **X**
- Spatial or size distribution **X**
- Trade-off with giant planets?
- Binaries?
- Planet Formation?



Heavy Elements Mass, P<50 days (mass-radius relation)

Mulders et al. 2015b



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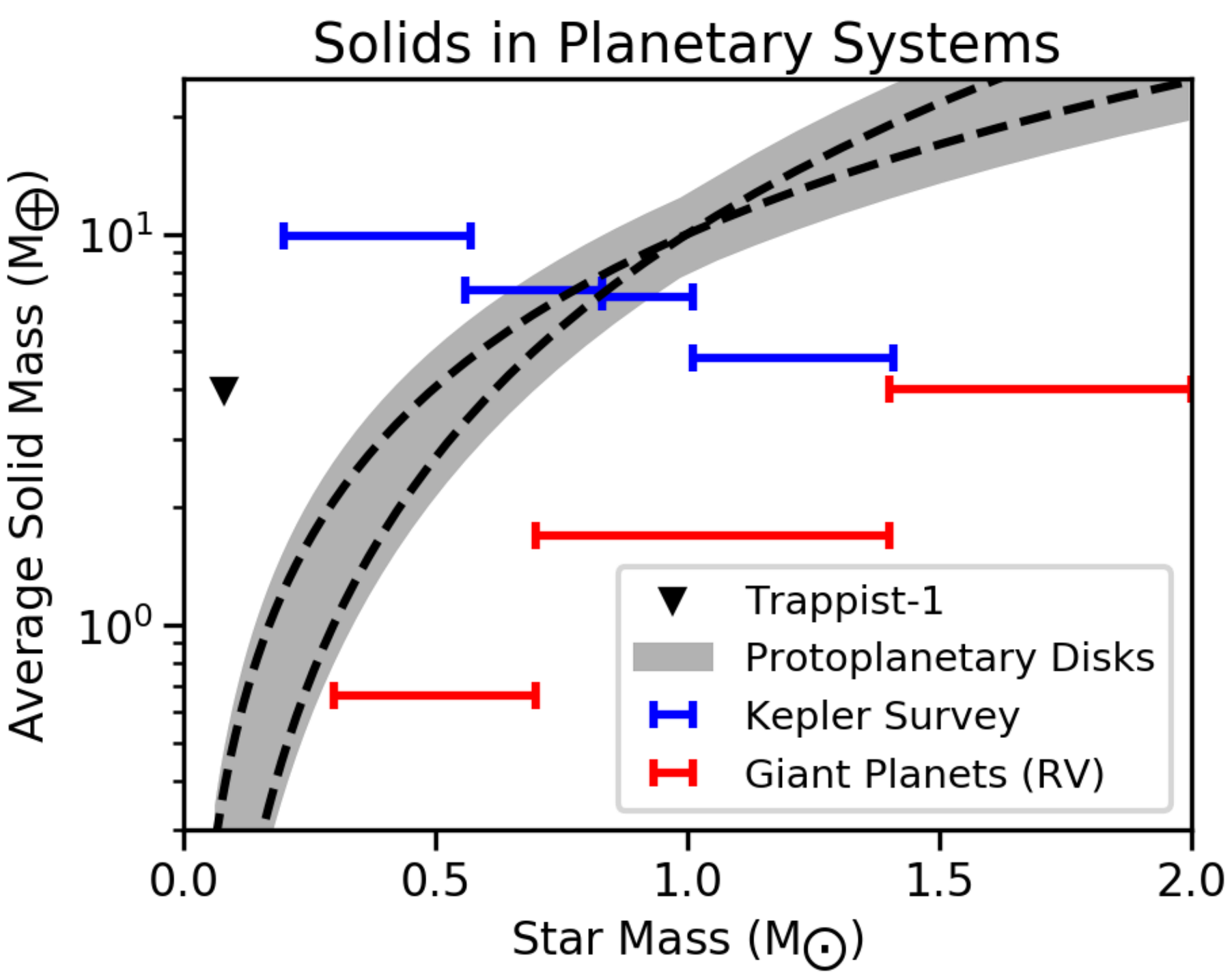


Comparison with disk solids

Mulders 2018, Handbook of Exoplanets

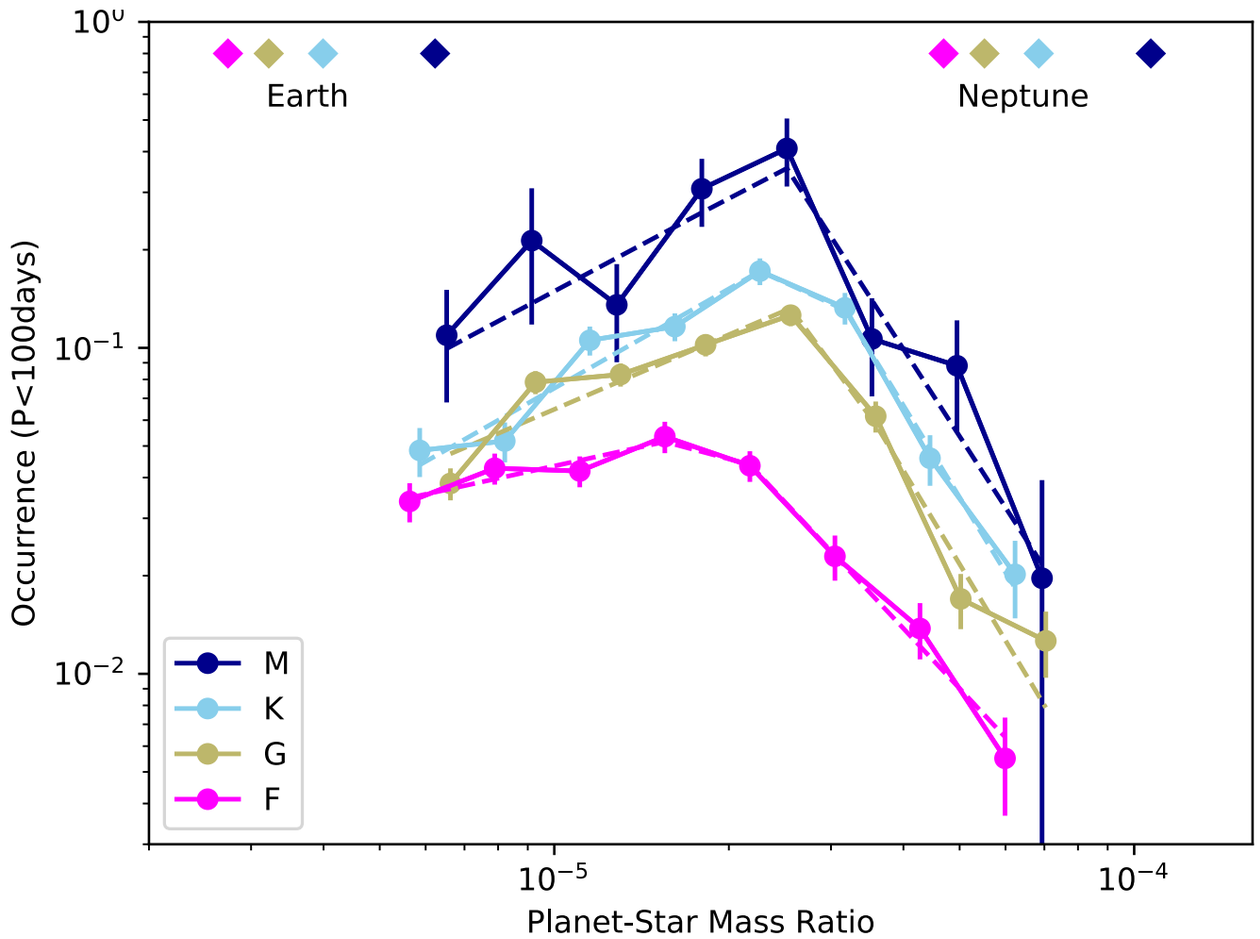
Sunlike Star

<1 au

Protoplanetary Disk

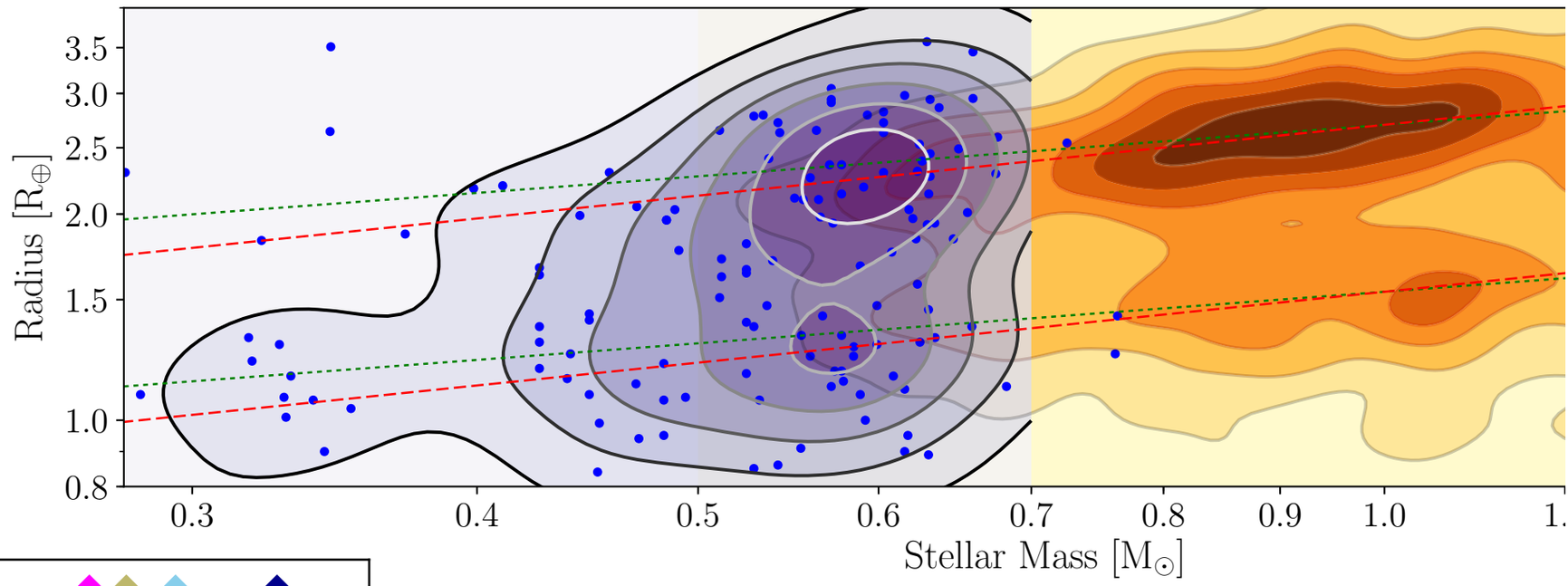
Migration

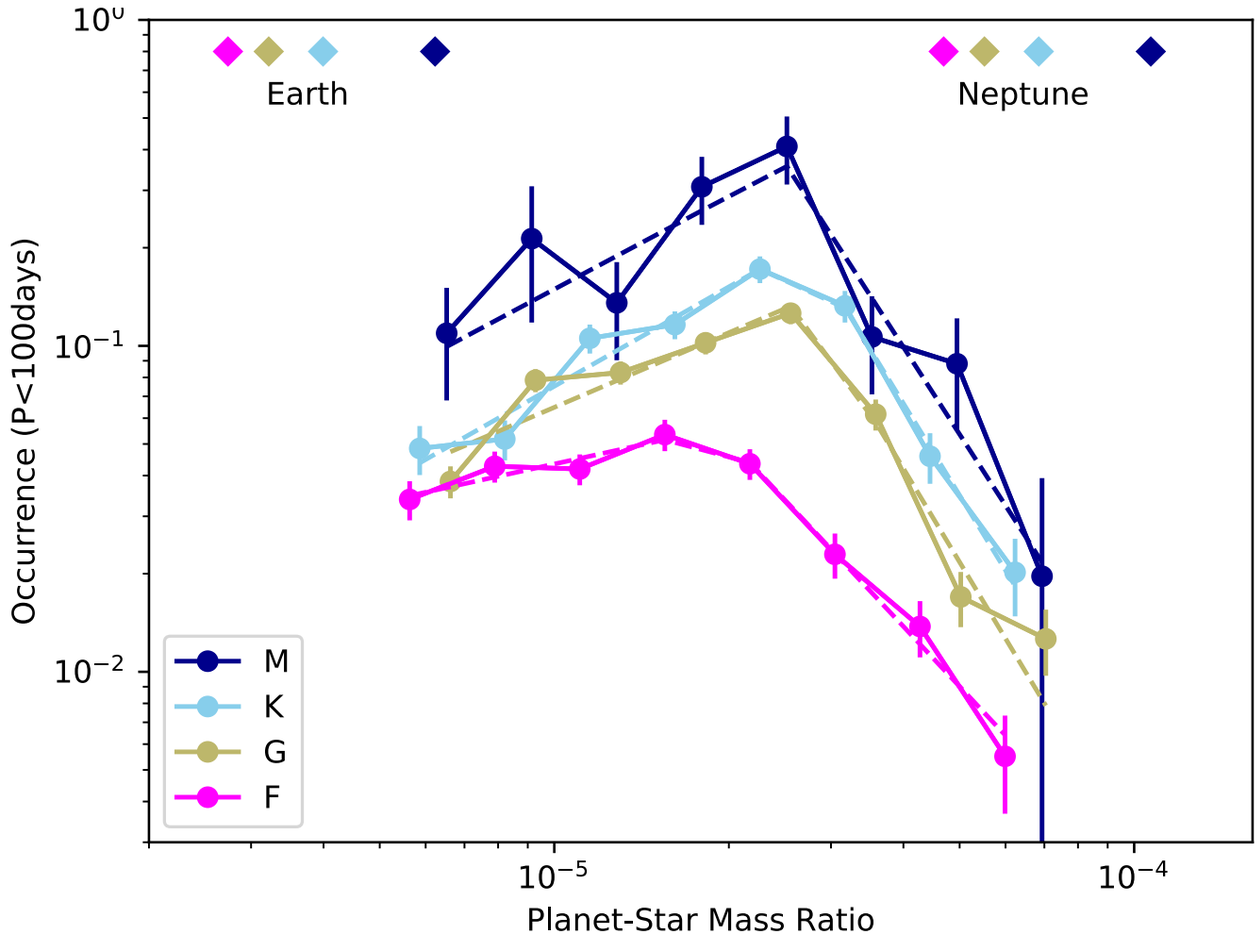
Red Dwarf



Planet Mass Dependence?

Pascucci+ 2018, Wu 2019

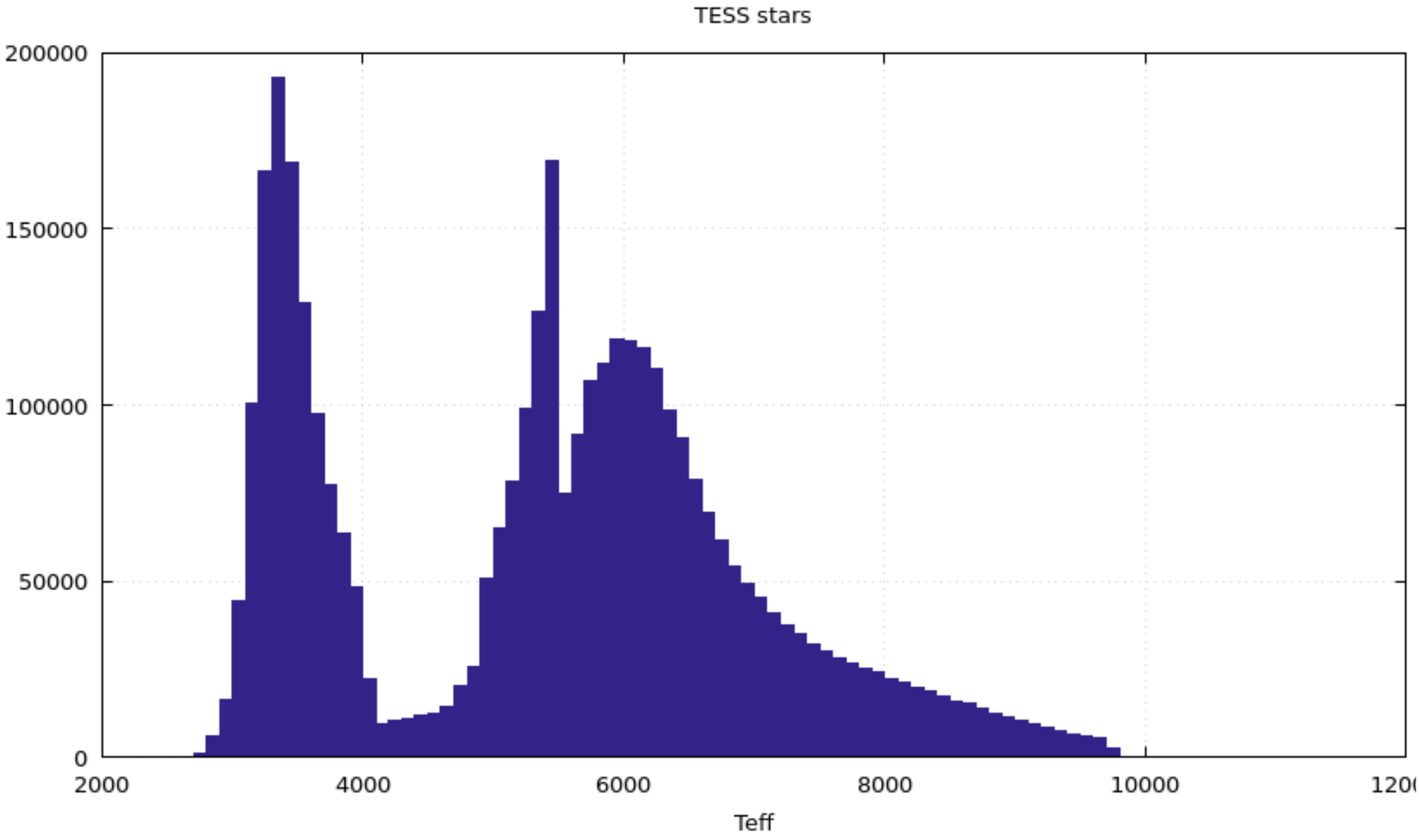




Planet Mass Dependence?

Pascucci+ 2018, Wu 2019

post-Kepler



K2 / TESS

Homogenous planet search & detection efficiency

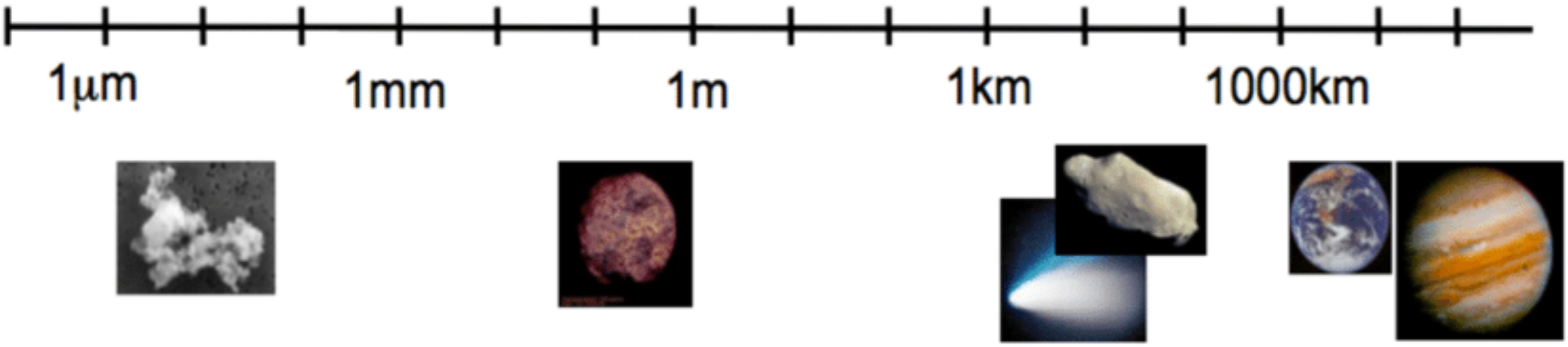
Protoplanetary Disk

Exoplanet

Which planet formation processes has right stellar mass dependence?

image credit: Kees Dullemond

Protoplanetary Disk



Exoplanet

Which planet formation processes has right stellar mass dependence?

image credit: Kees Dullemond

Protoplanetary Disk

Coagulation

Streaming Instability

Gravitational Collisions

Radial Drift

Pebble Accretion

Planet Migration

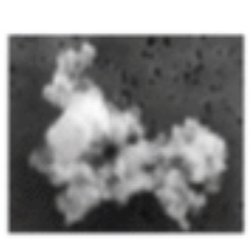
1μm

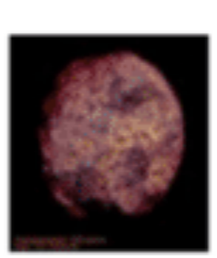
1mm

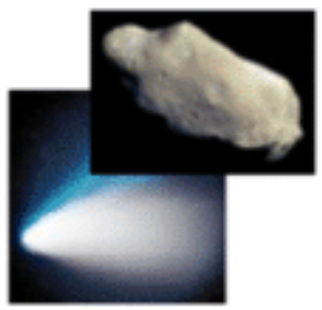
1m

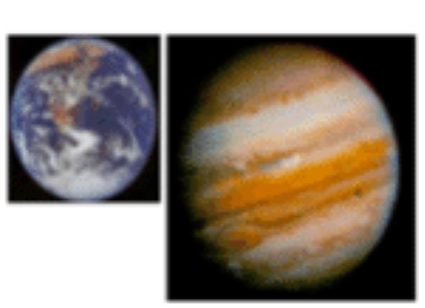
1km

1000km





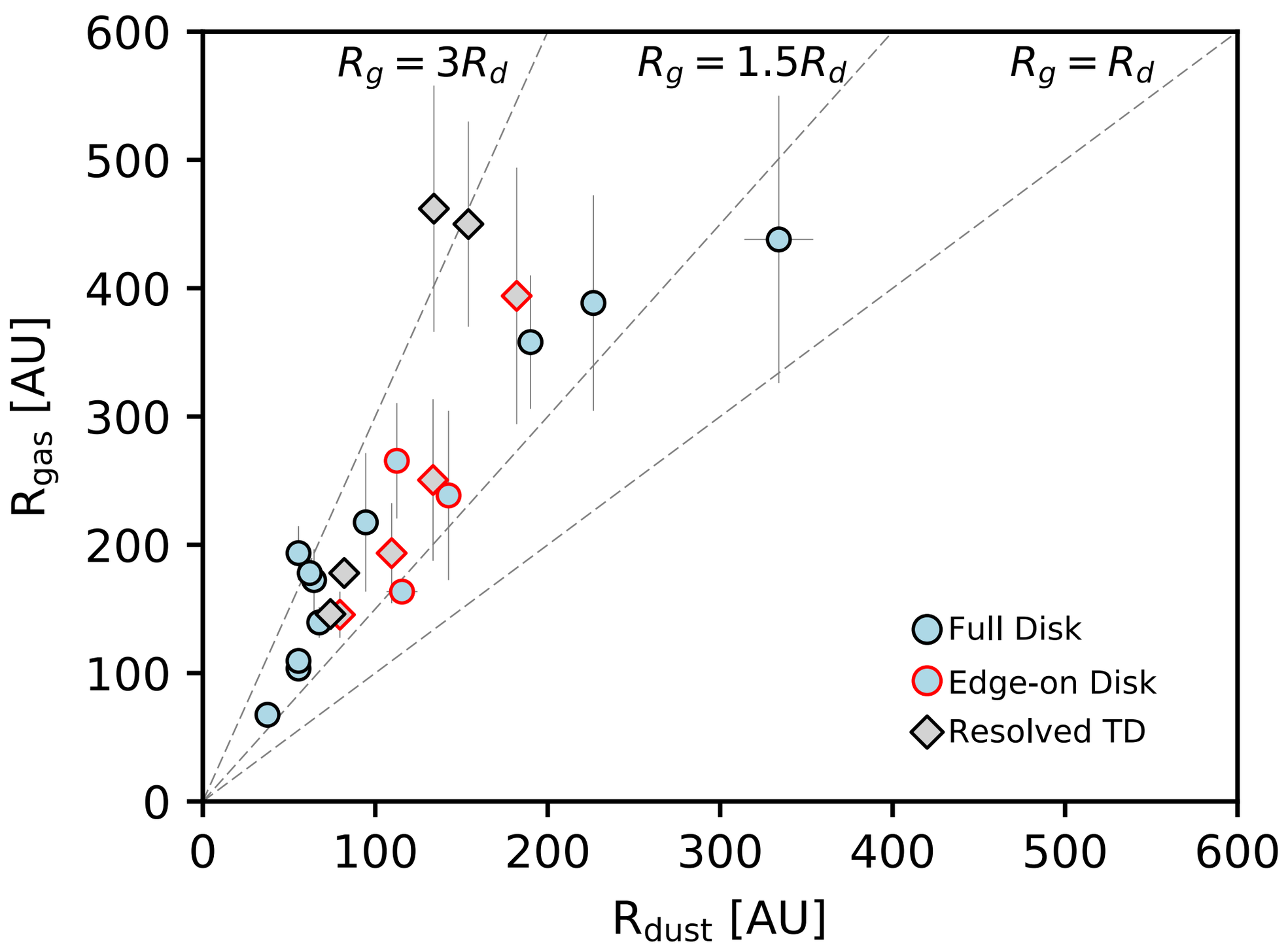




Exoplanet

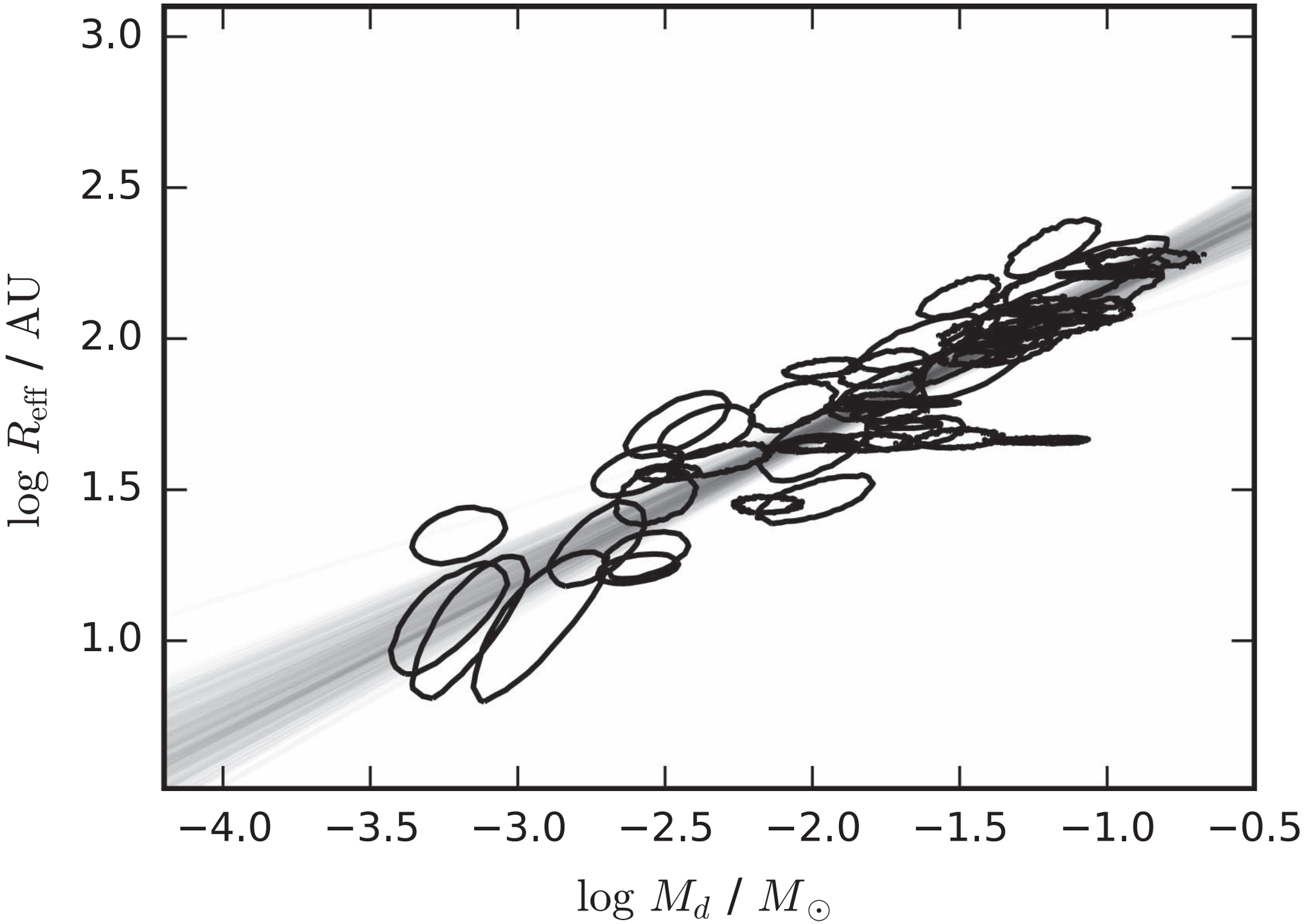
Which planet formation processes has right stellar mass dependence?

image credit: Kees Dullemond



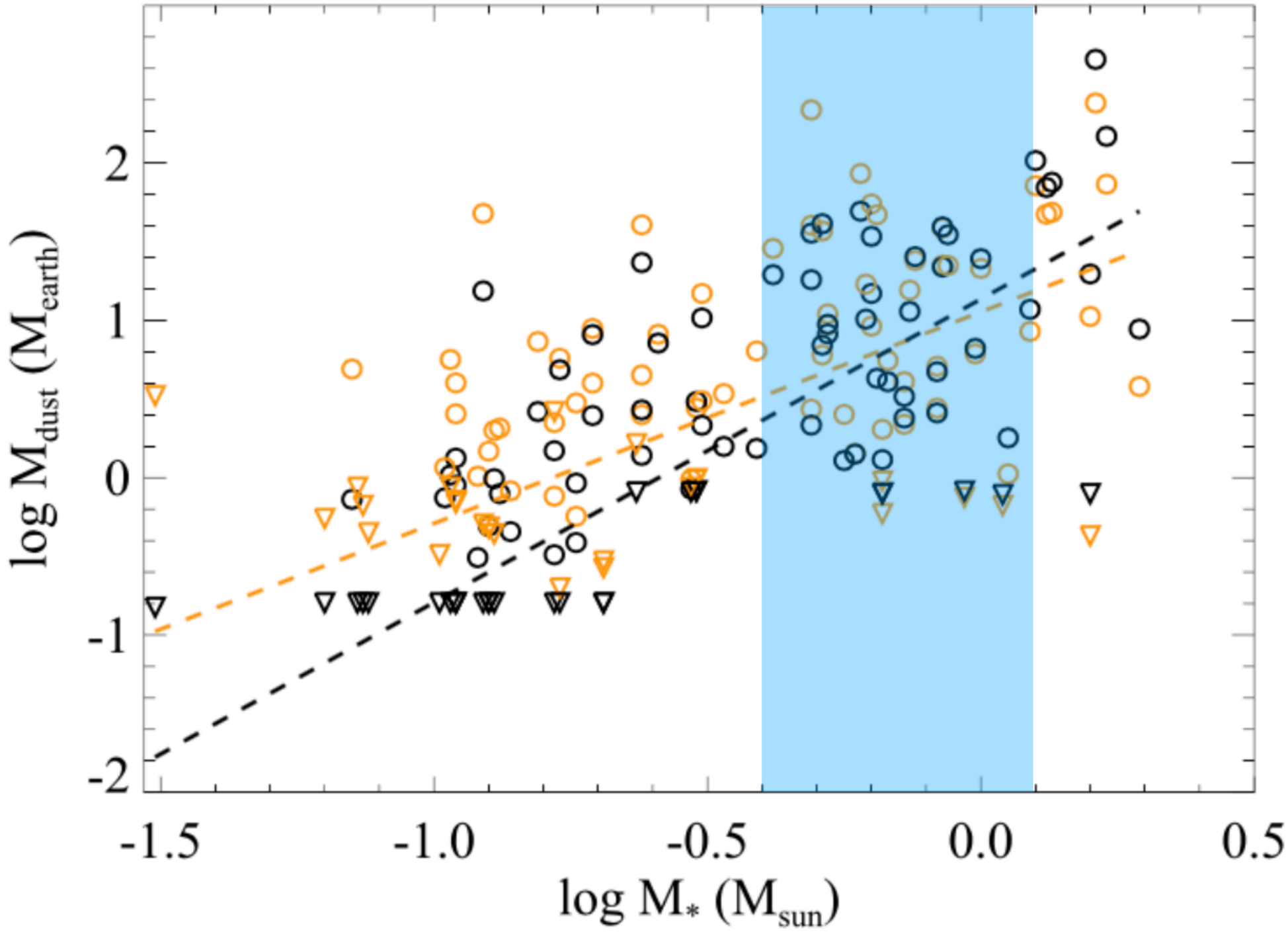
ALMA: Constraints on radial drift

Ansdell+ 2018



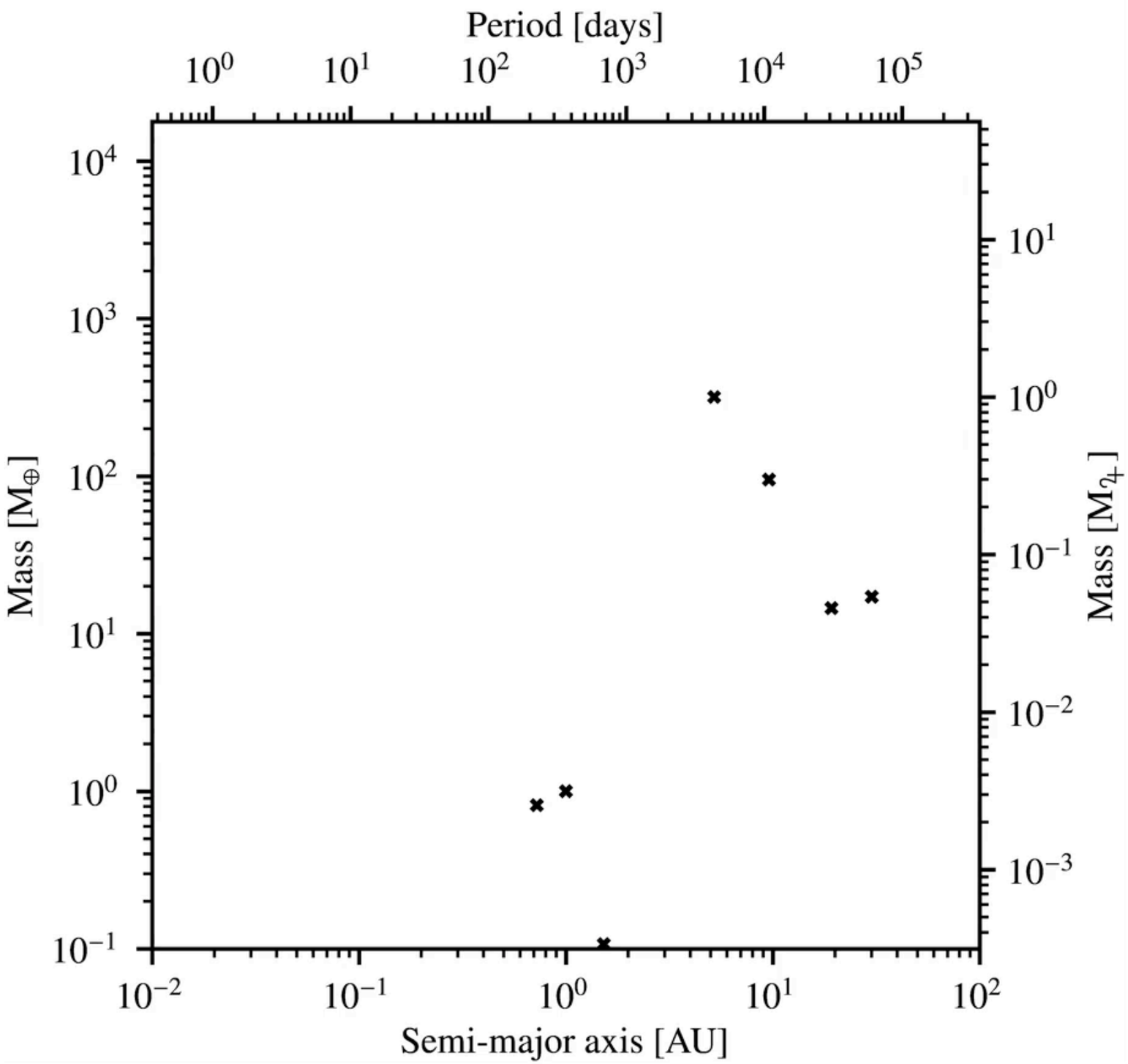
Low-mass disks are more compact

Tripathi+ 2017



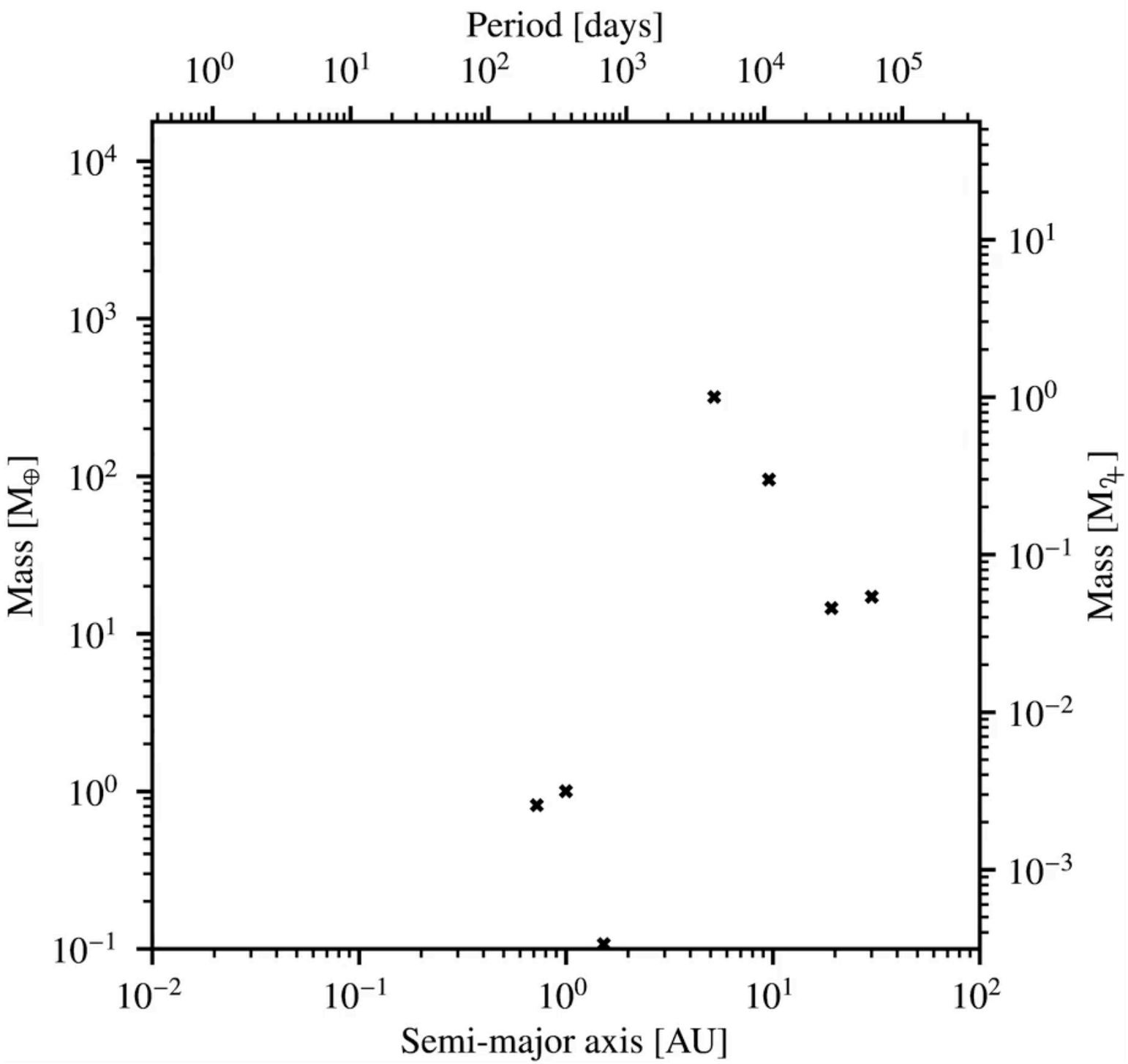
Dispersion in disk mass

Pascucci+ 2016



Population Synthesis (Bern models)

Mordasini 2018, Emsenhuber in prep



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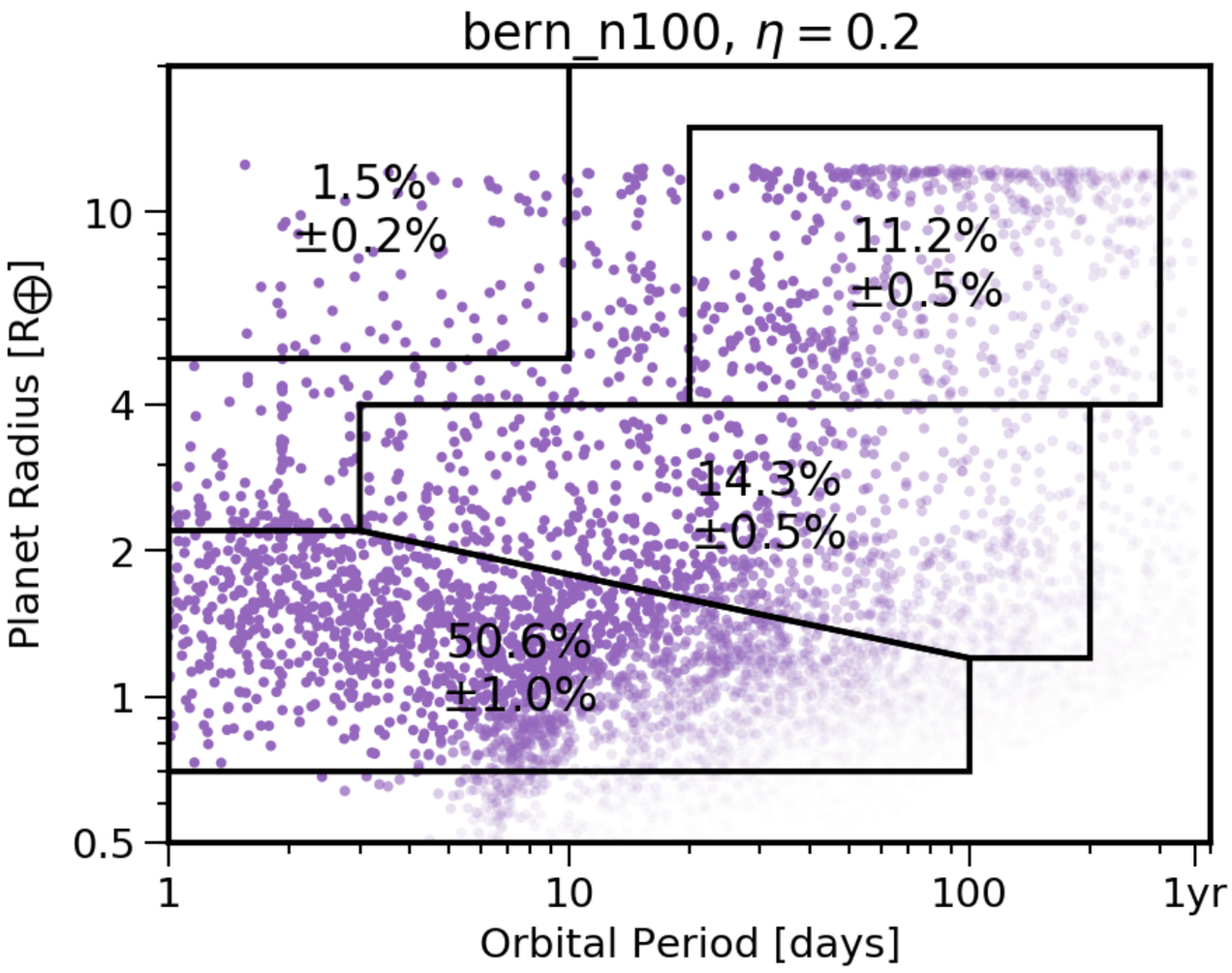
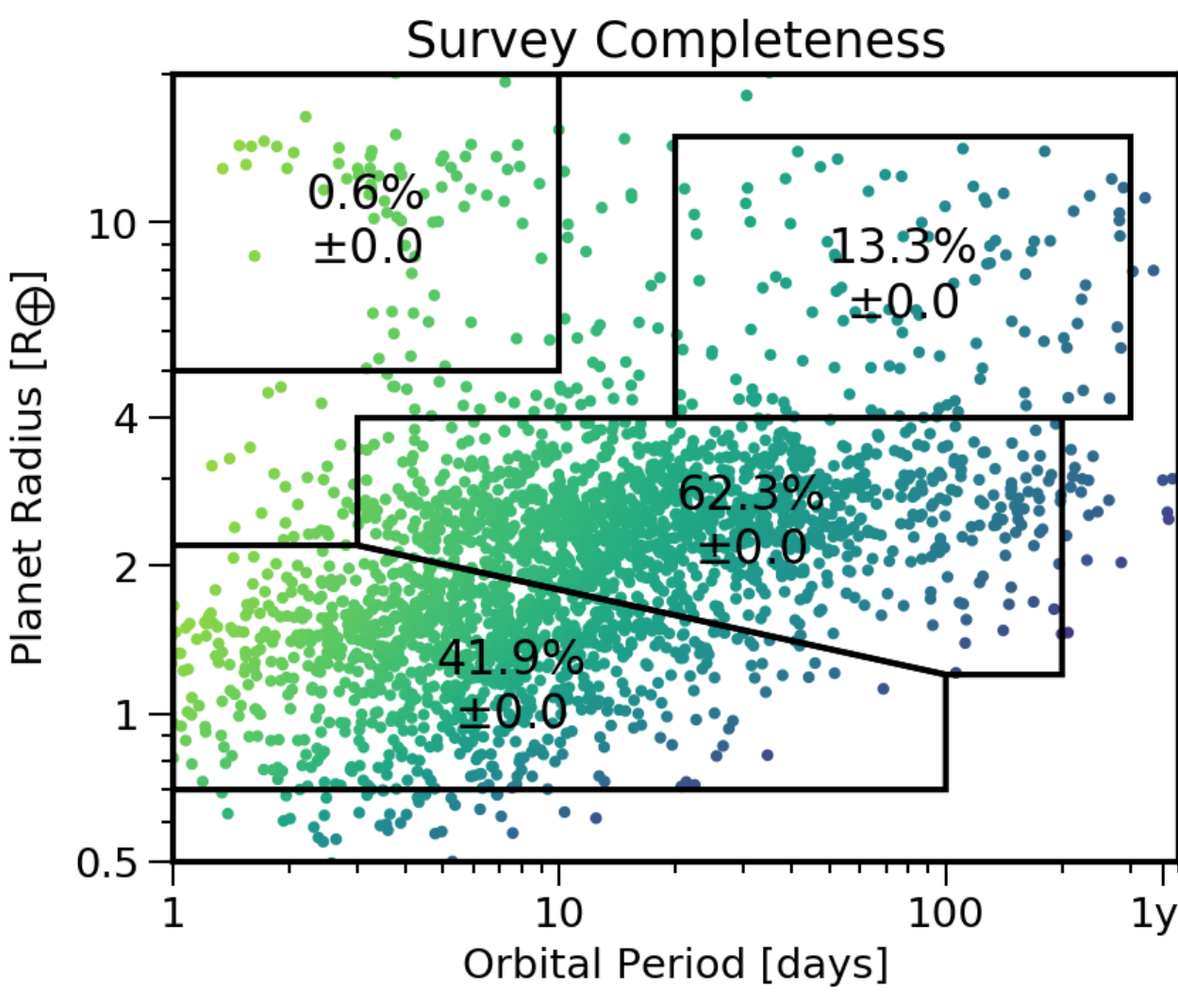
Bern Model



Observed Planets



Evaluating Population Synthesis Models

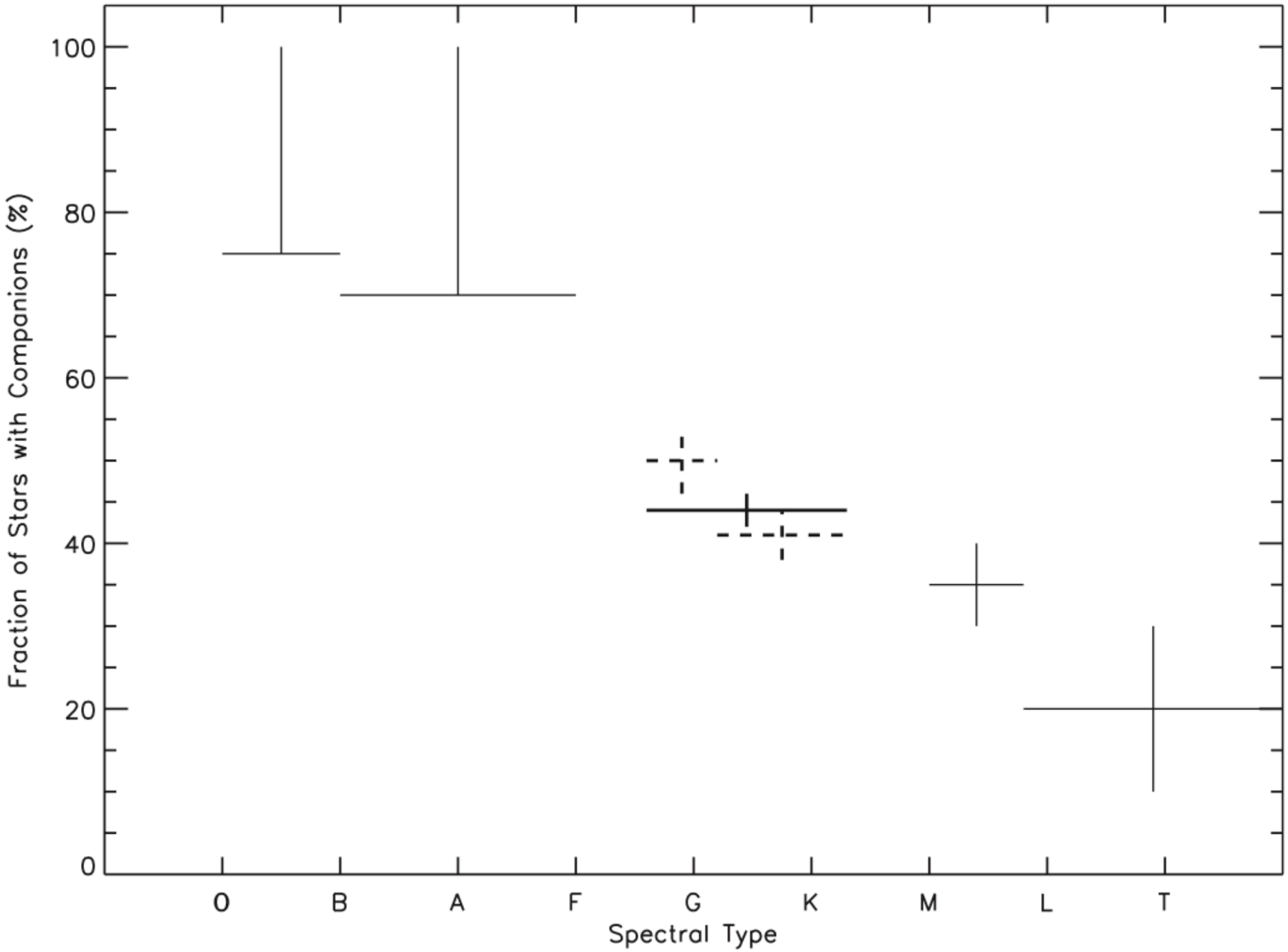
arXiv:1905.08804

Mulders+ 2019

The exoplanet population around stars of different masses

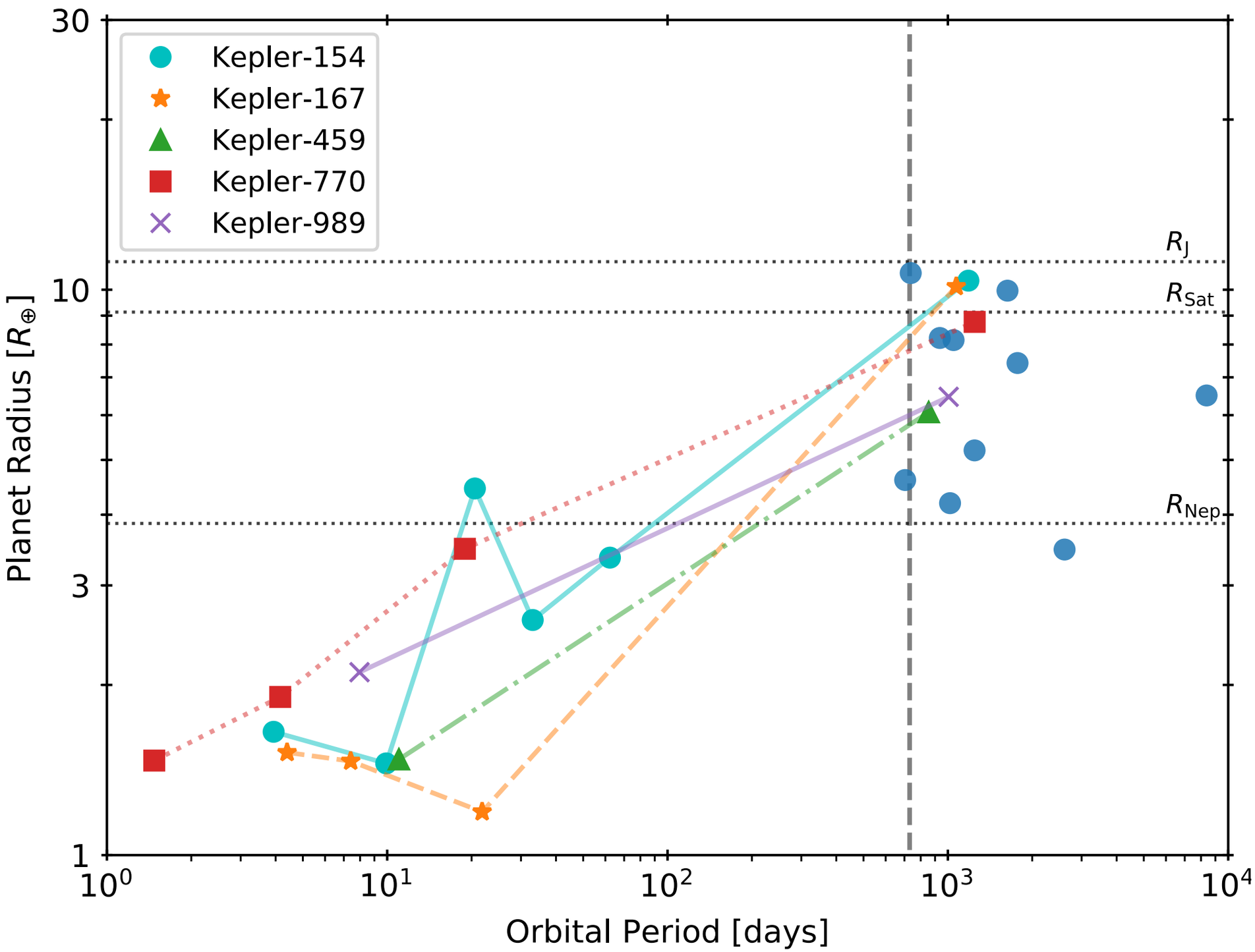
- Giant planets more common around more massive stars
- Sub-Neptunes are more common around low-mass stars
- Inconsistent with protoplanetary disk mass scaling laws
- Efficient radial drift or migration?

Backup Slides



Binary Fraction

Raghavan+ 2010



Cold Giants and Close-in Planets correlated

Herman+ 2019, Bryan 2016 & 2019